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EXPERIMENT SYSTEM DESIGN AND TEST PLAN  
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# GSFC

**GODDARD SPACE FLIGHT CENTER**  
**GREENBELT, MARYLAND**

## VANGUARD/PLACE EXPERIMENT SYSTEM DESIGN AND TEST PLAN

### SUMMARY

This document defines the system design, and describes an operational test plan, for demonstrating and testing the NASA-GSFC Position Location and Aircraft Communications Equipment (PLACE), at C band, using NASA's ship, the USNS Vanguard.

The Maritime Administration (MARAD), U. S. Department of Commerce, is a co-experimenter on board the Vanguard, having installed an Experimental Maritime Satellite Navigation/Communication (pseudo-random noise navigation code) System for a side-by-side comparison with the PLACE sidetone-ranging system.

The Vanguard/PLACE Experiment is the result of a "crash" in-house program to implement, and begin operational testing of the PLACE system in a period of time less than six months after inception. A pacing factor for the experiment was the March 28, 1973 departure date for the Vanguard, from Port Canaveral, Florida. The Vanguard's departure date was met by a sufficient margin that permitted operational-readiness checkout tests between the Rosman, N. C. Station, the Vanguard, and the ATS-5 satellite, as early as March 5, 1973.

The Vanguard/PLACE Experiment is divided into two phases: a Sea Test (approx. 30 days duration) to evaluate the position-location, 2-way voice, and 2-way data communications capability of PLACE; and a Trilateration Test (approx. 60 days duration) to position-fix the ATS-5 satellite using the PLACE system.

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## VANGUARD/PLACE EXPERIMENT SYSTEM DESIGN AND TEST PLAN

### ACKNOWLEDGMENTS

The NASA-Goddard Communications and Navigation Division (Code 750) originated the concept of employing NASA's ship, the USNS Vanguard, to demonstrate and test the Position Location and Aircraft-Communications Equipment (PLACE) at C band. In particular, Mr. James L. Baker made the initial suggestion to use the Vanguard for this purpose.

The Bell Aerospace Company, Buffalo, New York, manufactured the PLACE electronic hardware for the Rosman, N. C. and Mojave, California stations, and the PLACE equipment for the Vanguard, under the direction of Messrs. E. Rupp, Karl R. Gohlke and Steve Martin. Bell Aerospace also provided field-support personnel for the Rosman and Vanguard terminals.

Mr. Harry Feigleson, Program Manager, of the Maritime Administration (MARAD), U. S. Department of Commerce, provided planning assistance as a co-experimenter, and supplied the 2.5-ft-diameter dish antenna, including a C-band receiver, for the Vanguard. This was accomplished under the direction of Mr. Michael W. Mitchell, Applied Information Industries (AII), Moorestown, New Jersey (MARAD Contract).

The loan of the TRANSATEL, C-band, transmitter terminal, from the General Electric Company (Valley Forge, Pa.) for use at NASA's station at Rosman, N. C., is appreciated. Also, the helpful comments made by Mr. Roy E. Anderson, Project Manager, General Electric Company (Schenectady, New York), in the review of the Vanguard/PLACE Test Plan, are acknowledged.

The ATS Project Office (Code 460) is commended for their overall coordination of the satellite and ground-station support for the Vanguard/PLACE Experiment; the ATS Operations Control Center (ATSOCC) was especially helpful in this regard.

The indispensable operational support provided by the NASA-Goddard NETWORKS DIRECTORATE (CODE 800), at the Rosman, N. C., Vanguard and Mojave, California terminals, is deeply appreciated.

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The effort of the Network Engineering Division (Code 810), Antenna Systems Branch (Code 811), and RF Systems Branch (Code 813) is appreciated for the feed modification of the 15-ft-dish antenna, and for installation of the 4-GHz Monitor Link at the Rosman Station.

The satellite-ephemeris data provided by the Mission Support Computing and Analysis Division (Code 580) is also appreciated.

The operational aspects of the Vanguard/PLACE Experiment were directed by Mr. Richard Waetjen, Program Manager (Code 752); Mr. Walter K. Allen (Code 752) is the Principal Investigator for the PLACE Experiment; and Mr. Sheldon Wishna (Code 752) was Technical Officer for the procurement of the PLACE aircraft modems used in the experiment.

Dr. Ahmad Ghais, Mobile Applications (Code 752), Messrs. C. A. White (Code 750), and Dean Bonnell (Code 861.2) provided coordination between NASA and MARAD.

Vanguard/PLACE personnel on board the Vanguard, for the Sea Tests, include:

- Mr. Sheldon Wishna, NASA/GSFC, Code 752
- Mr. James Christo, NASA/GSFC, Code 752.
- Mr. Karl R. Gohlke, Bell Aerospace Company
- Mr. Richard Snyder, Bell Aerospace Company.

The information contained in Appendix 8, "Voice Tests, Vanguard/PLACE Experiment," was prepared by Messrs. S. Wishna and W. Risley, of NASA/GSFC Code 752. Also, the information in Appendix 9, "Satellite Trilateration Theory and Computations" was provided by Mr. H. Winter, Bell Aerospace Co., Buffalo, New York.

Finally, the individual and corporate contributions made by the following "Key Personnel" were invaluable.

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## VANGUARD/PLACE EXPERIMENT SYSTEM DESIGN AND TEST PLAN

### I. INTRODUCTION

This Center originated a maritime experiment to test the GSFC Position Location and Aircraft Communications Equipment, Reference 1, (PLACE), at C-band (due to lack of maritime L-band capability), with NASA's ship, the USNS Vanguard (Figure 1), and the Applications Technology Satellite(s) (ATS), ATS-3 and ATS-5, now in orbit. The Vanguard/PLACE Experiment (Reference 2) was designed to give a preliminary evaluation of the PLACE concept one year in advance of its scheduled tests with ATS-F, scheduled for launch in April 1974.

Quoting directly from Reference 3: "The experiment proposed in your letter dated November 20, 1972, using PLACE equipment on the USNS Vanguard is approved."

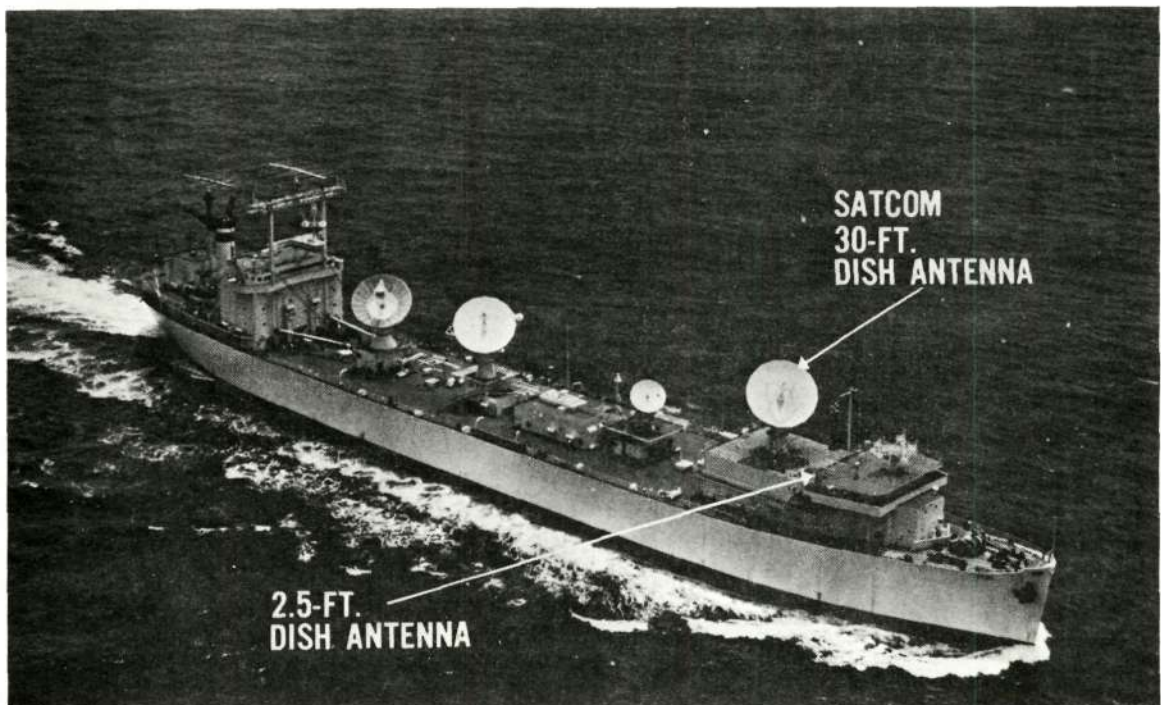


Figure 1. NASA Ship, USNS VANGUARD, Showing Location of 30-Ft. & 2.5-Ft, C-Band, Dish Antennas for Place Experiment.

The principal functions of the Vanguard/PLACE Experiment are as follows:

- Real-time Position Location of Ship, by two-way sidetone ranging, through two synchronous satellites (ATS-5 and ATS-3).
- Duplex (two-way) Voice Communication (shore-to-ship and ship-to-shore).
- Duplex (two-way) Data Transmission.
- Data and Voice Multiple Access
- Trilateration Tests to Accurately Position-Fix ATS-5 Satellite.

The principal objectives of the Vanguard/PLACE Experiment are:

- (1) Early Demonstration of PLACE Concept in a Maritime Environment.
- (2) Offer the U. S. Maritime Administration (MARAD), Reference 4, an Alternate System, which includes Duplex Voice.
- (3) Determination of Position-Fixing Error for a Mobile User (Vanguard ship), compared to on board, precision, Navigation Instrumentation.
- (4) Early Demonstration of Duplex-Voice Communications, Duplex-Data Transmission, and Mobile-User Multiple-Accessing Techniques.
- (5) Demonstration of PLACE Trilateration Capability for Position-Fixing a Synchronous Satellite (ATS-5) by Means of Sidetone-Ranging Measurements from three, Earth-Based, Trilateration Stations.

The Vanguard/PLACE Experiment has been divided into two phases: (1) a Sea Test (approx. 30 days duration) using C-Band links (4/6 GHz) between the Vanguard ship, the ATS-5 and ATS-3 satellites, and the NASA-Tracking Network Station located at Rosman, North Carolina, and (2) a Trilateration Test (approx. 60 days duration) to position-fix the ATS-5 satellite, with the PLACE system in the Trilateration Mode, using C-Band links between three trilateration stations including the Vanguard, Rosman and Mojave (California) stations. The Vanguard ship will be docked at Mar Del Plata, Argentina, South America, during the Trilateration Test Phase.

The first documentation on the PLACE system originated from NASA-Goddard in April 1967 which was later updated - a recent update is Reference 1. In early 1970, a hardware contract for several aircraft transponders (L-Band

Transmitter/Receiver and Modem, Reference 5) was initiated with the Bell Aerospace Company; consequently, in mid-1971, a similar contract, (Reference 6) was placed for PLACE Ground Equipment (PGE), for an approved PLACE Experiment on the ATS-F satellite.

In the Fall of 1972, members of the NASA-Goddard Communications and Navigation Division (Code 750) originated the concept of employing the Vanguard to demonstrate the PLACE system at C-Band (4/6 GHz), a frequency-spectrum region free of propagation anomalies including ionospheric delay and scintillation.

A crucial factor was the realization that the Vanguard's 30-ft-diameter dish antenna had sufficiently high effective-radiated-power (ERP) to employ the ATS-5 satellite's, omnidirectional, C-Band antenna (transmit and receive) which made possible a complete PLACE Experiment -- including ship position-fixing, 2-way voice communications and 2-way data communications. Utilization of the omnidirectional antenna circumvents a number of problems due to satellite spin; both ATS-5 and ATS-3 satellites are spinning and the directive C-band radiation pattern thus also spins.

However, in order to make the Vanguard/PLACE Experiment viable, a minimal amount of additional PLACE hardware electronics was required on the Vanguard -- this equipment, contained in a single rack, was subsequently procured.

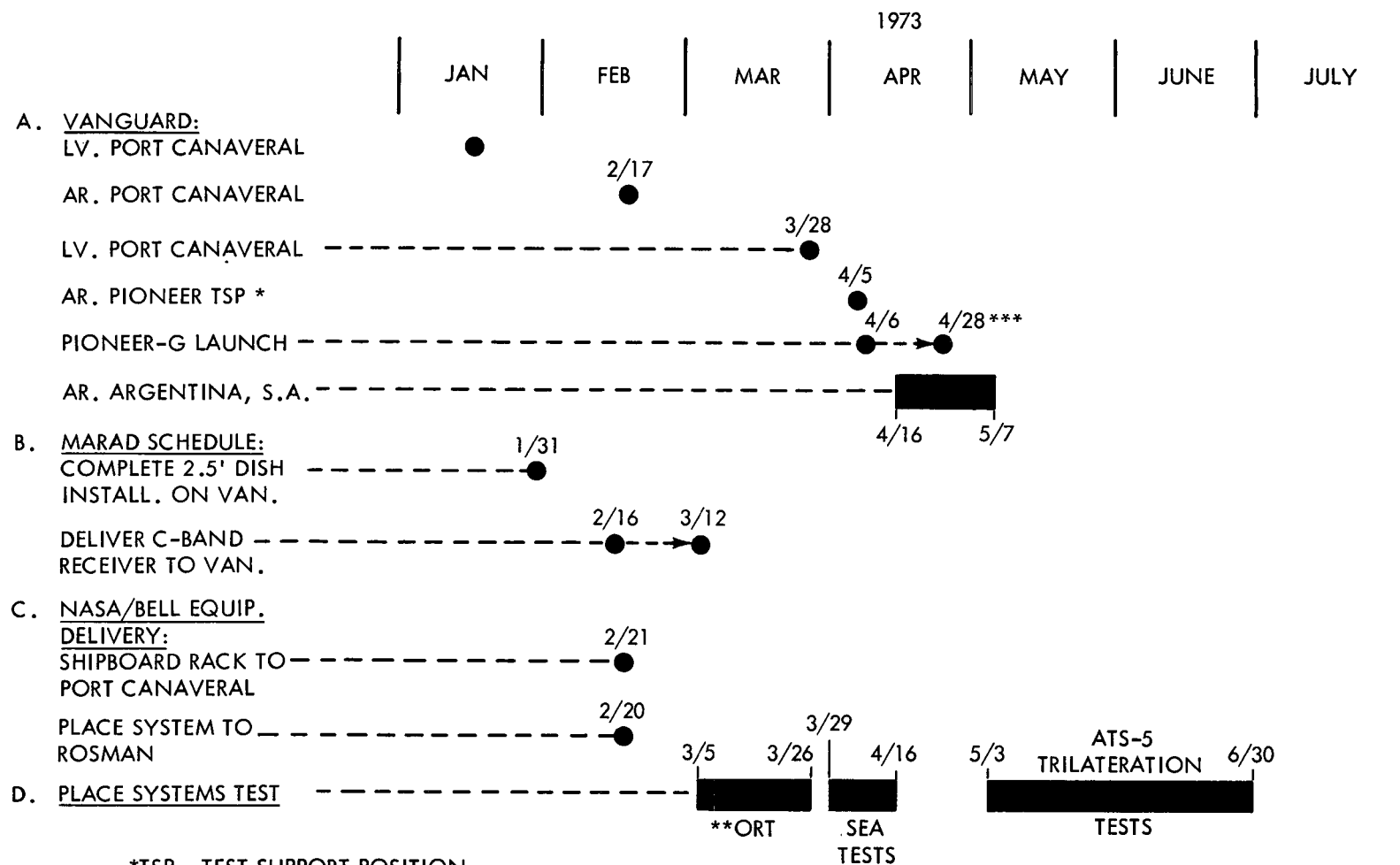
In addition, the availability of the NASA-Vanguard ship allowed the Maritime Administration (MARAD), U. S. Department of Commerce, to become a co-experimenter by deploying a MARAD Ship Terminal (Reference 4) on the Vanguard for a side-by-side comparison with the NASA-PLACE system. Furthermore, this had the advantage of reducing costs for the NASA-PLACE Experiment since MARAD's C-Band, 2.5-ft., dish antenna, and C-Band Receiver, could be time-shared on the Vanguard by both experimenters.

A pacing factor in the milestone schedule (Table 1), for the joint NASA-MARAD Experiment with the Vanguard ship, was the Vanguard's March 28, 1973 sailing date (from Port Canaveral, Florida) in support of the NASA PIONEER-G mission.

## II. VANGUARD/PLACE EXPERIMENT SYSTEM DESIGN

The primary function of the NASA-PLACE system is to provide simultaneous surveillance and position-fixing for up to 250 mobile users, in addition to providing 2-way voice communications and 2-way data communications between a ground station and the mobile users.

Table 1  
Milestone Schedule for VANGUARD/PLACE Tests



\*TSP - TEST SUPPORT POSITION  
 \*\*ORT - OPERATIONS READINESS TESTS  
 \*\*\*END OF PIONEER WINDOW

Table 2  
Typical Format of Rosman PLACE PGE/PCC Real-Time Printout

User Ident	GMT Time Hr/Min/Sec	Mobile User				Doppler Dopn	S&R TDM Assign- ment		Voice - V, & Data, D Status VDVDVDEGF	Round Trip Range to Satellite 1, RT1 (Meters)	Round Trip Range to Satellite 2, RT2 (Meters)
		Position Veh. Lat/Long (Deg, Min)		Velocity North VN (kts)	Velocity East VE (kts)						
444	00/00/00.000	N047/19.15	W094/09.85	+025.1	-162.1	064	02	04	011011000	1.51895026E 08	1.51894890E 08
444	00/00/00.000	N047/19.21	W094/10.13	+026.0	-156.1	064	02	05	011011000	1.51895251E 08	1.51894996E 08
444	00/00/00.000	N047/19.28	W094/10.69	+027.3	-162.3	064	02	06	011011000	1.51895124E 08	1.51895219E 08
444	00/00/00.000	N047/19.30	W094/11.14	+025.9	-163.5	064	02	07	011011000	1.51894974E 08	1.51894999E 08
444	00/00/00.000	N047/19.33	W094/11.55	+024.5	-162.8	064	02	08	011011000	1.51894941E 08	1.51894913E 08
444	00/00/00.000	N047/19.41	W094/12.13	+026.7	-169.3	064	02	09	011011000	1.51895061E 08	1.51895293E 08
444	00/00/00.000	N047/19.45	W094/12.49	+026.3	-165.9	064	02	00	011011000	1.51895088E 08	1.51895060E 08
444	00/00/00.000	N047/19.47	W094/12.86	+024.9	-163.4	064	02	01	011011000	1.51894986E 08	1.51894936E 08
444	00/00/00.000	N047/19.50	W094/13.34	+024.1	-165.5	064	02	02	011011000	1.51894884E 08	1.51894973E 08
444	00/00/00.000	N047/19.55	W094/13.82	+024.7	-167.5	064	02	03	011011000	1.51894954E 08	1.51895077E 08
444	00/00/00.000	N047/19.62	W094/14.17	+025.7	-163.9	064	02	04	011011000	1.51895131E 08	1.51895075E 08
444	00/00/00.000	N047/19.64	W094/14.57	+024.6	-162.7	064	02	05	011011000	1.51894966E 08	1.51894935E 08
444	00/00/00.000	N047/19.70	W094/15.06	+025.6	-165.5	064	02	06	011011000	1.51895022E 08	1.51895121E 08
444	00/00/00.000	N047/19.70	W094/15.31	+022.8	-157.9	064	02	07	011011000	1.51894934E 08	1.51894690E 08
444	00/00/00.000	N047/19.76	W094/15.72	+023.6	-158.0	064	02	08	011011000	1.51895037E 08	1.51894926E 08
444	00/00/00.000	N047/19.83	W094/16.22	+025.7	-161.4	064	02	09	011011000	1.51895131E 08	1.51895133E 08
444	00/00/00.000	N047/19.89	W094/16.67	+026.1	-162.6	064	02	00	011011000	1.51895074E 08	1.51895058E 08
444	00/00/00.000	N047/19.95	W094/17.14	+027.2	-164.4	064	02	01	011011000	1.51895143E 08	1.51895168E 08
444	00/00/00.000	N047/19.96	W094/17.50	+024.9	-161.7	064	02	02	011011000	1.51894971E 08	1.51894856E 08

In order to obtain an independent position-fix for a mobile user (e.g., aircraft or ship), three range measurements are required: (1) range from satellite 1 (ATS-5) to the mobile user,  $R_1$ , (2) range from satellite 2 (ATS-3) to mobile user,  $R_2$ , and (3) range from the Earth's geocenter to the mobile user,  $R_3$ .  $R_1$  and  $R_2$  are computed directly from sidetone-ranging measurements made by the PLACE system; whereas the location of the geocenter is known a priori – it remains only to measure the height (altitude in case of aircraft) above sea level,  $h$ . A real-time printout of each user's position is made at the PLACE control Center (PCC); a typical format is shown in Table 2.

Having thus available specific values of  $R_1$ ,  $R_2$  and  $R_3$  for a given mobile user, the PLACE system computes (in real time) two independent Line-of-Positions\* (LOP 1 and LOP 2, Figure 2) for that mobile user; two possible user positions are determined – the actual position,  $P_1$ , and an ambiguous position,  $P_2$ , the latter being resolved by a priori information. Surveillance and Ranging (S & R) is performed by a single S & R channel to ATS-5 which consists of four range tones and a DPSK, 600 bps, Low-Rate-Data signal, Figure 3(a). The S & R transmission from Rosman to the Vanguard, via ATS-5, is continuous; however, the Vanguard counts time to an assigned time slot and replies with an S & R signal burst which includes the returned ranging tones. Timing synchronization is established through 600-bps data transmissions, in the S & R channel.

A second set of range tones, consisting of only three tones, is transmitted from the Rosman Station to the ATS-3 satellite, Figure 3(b). The NASA-PLACE equipment on the Vanguard contains three digital phase-lock loops, phase locked to range tones intermittently received from ATS-3, which recover and reproduce continuous (but delayed) replicas of the original range tones.

The two sets of range tones, Figure 3(a) and 3(b), each contain a high range-tone frequency, at 8575 Hz, which is used for "fine" range measurements. The first set of rangetones, Figure 3(a), provide a low-difference frequency of 25 Hz which is sufficient for completely unambiguous ranging; whereas the second set of rangetones, Figure 3(b), provide a low-difference frequency of 175 Hz, which will give a range ambiguity of only 467 n mi. (one way). However, the Vanguard's, on board, navigation measurements will be used to eliminate the ambiguity at 467 n mi.

The reply S & R channel from the Vanguard to ATS-5 is operated in a time-division-multiplex (TDM) Mode, Figure 4, in order to handle sequentially up to 250 mobile users. The update rate is once per 64 sec., for each user; an optional update rate of 10 data points per 64 sec (approx. 1 minute) is also available.

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\*An LOP is generated by a range measurement from one satellite to a user (e.g.,  $R_1$ ), and range to geocenter,  $R_3$ .

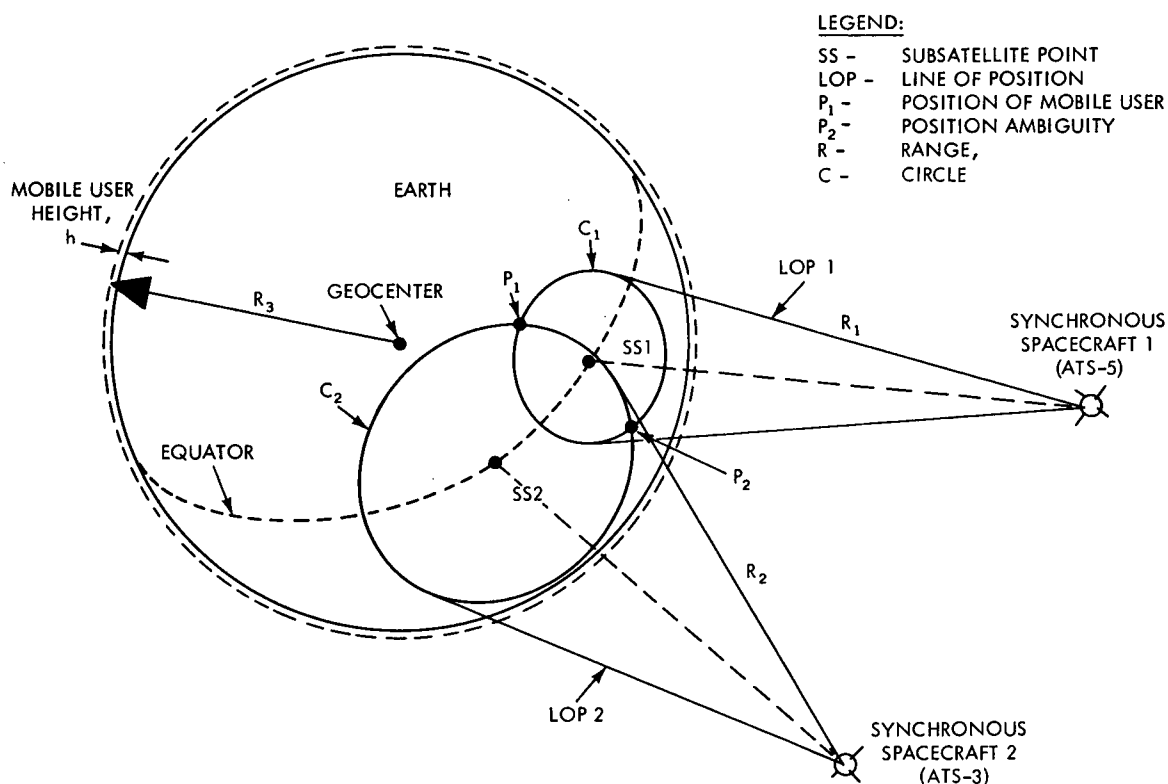


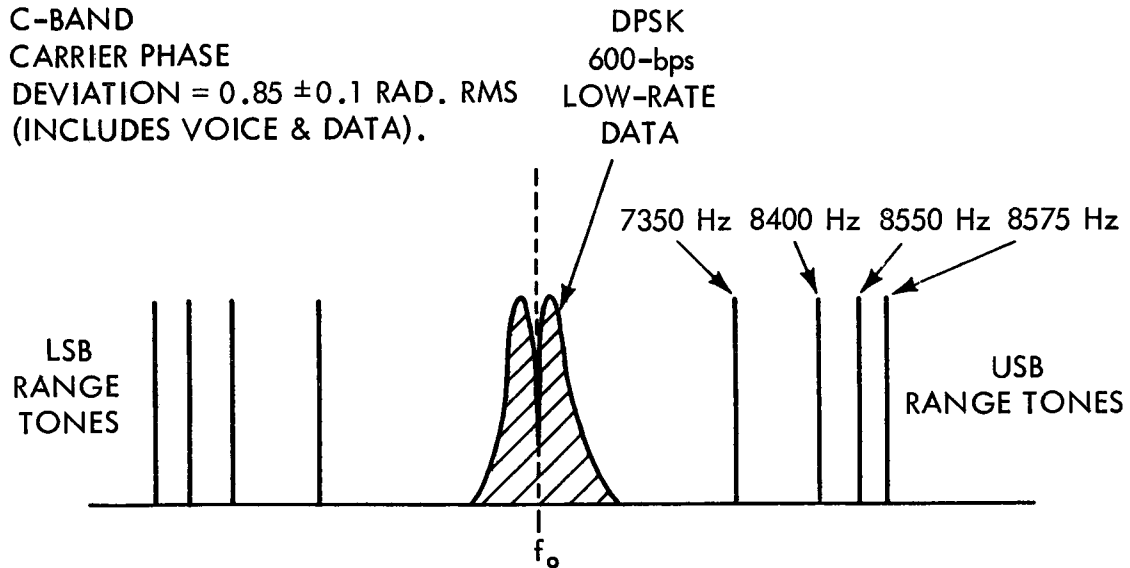
Figure 2. Mobile User Position Fixing By Direct Ranging to Two Spacecraft

The TDM slot assignments for the three trilateration stations (Rosman, Mojave and Vanguard), for the ATS-5 Trilateration Tests, are also shown in Figure 4; an update rate of 10 ranging measurements per 64 sec will be used.

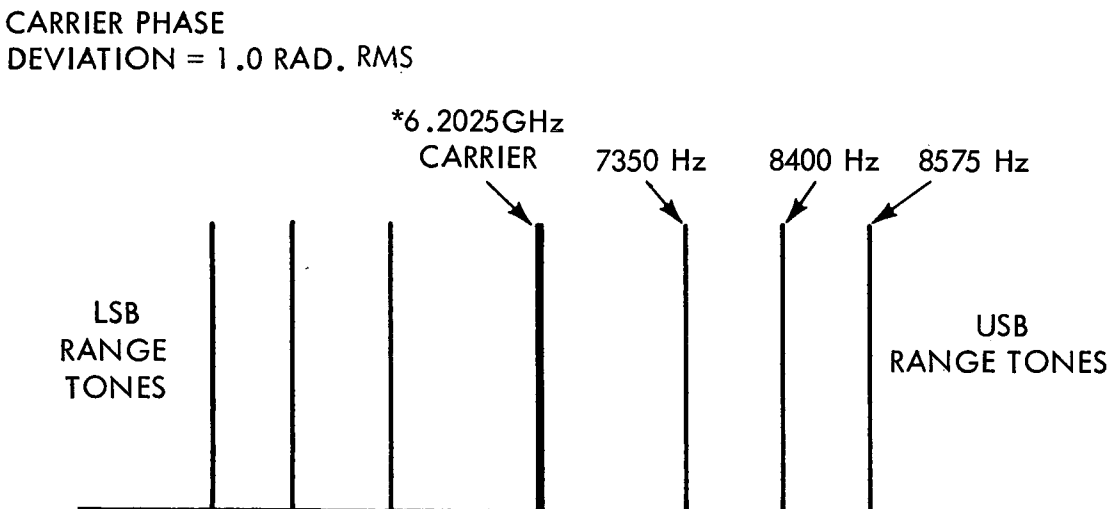
The PLACE frequency channels, for the 4 GHz and 6 GHz RF links between Rosman, ATS-5 and the Vanguard, consist of a single S & R channel, three voice channels, and three High-Rate Data (1200 bps) channels, Figure 5(a) and 5(b). The voice and data channels are frequency-division multiplexed (FDM). The voice channels employ an adaptive, narrowband, frequency-modulation (NBFM) technique; whereas the data channels use differentially coherent phase-shift-keyed (DPSK) modulation.

However, the PLACE Aircraft Modem on board the Vanguard can transmit only one voice and one data channel simultaneously (e.g. V<sub>1</sub> and D<sub>1</sub>), but can receive up to 3 voice and 3 data channels.

The Vanguard/PLACE Experiment utilizes the Rosman Station, the Vanguard, and the ATS-5 and ATS-3 satellites for the Sea Tests; the Mojave, California station is required only for ATS-5 Trilateration Tests (Figure 6).



(a) Surveillance & Ranging Channel Frequency Spectrum, Rosman-to ATS-5 to Vanguard-and-Return Links.



\*4.11 GHz ATS-3 TO-VANGUARD LINK

(b) Phase Modulated, Sidetone-Ranging, Frequency Spectrum, Rosman-to ATS-3 to-Vanguard Link.

Figure 3. Sidetone Ranging Frequency Spectrum, Vanguard/Place Experiment.

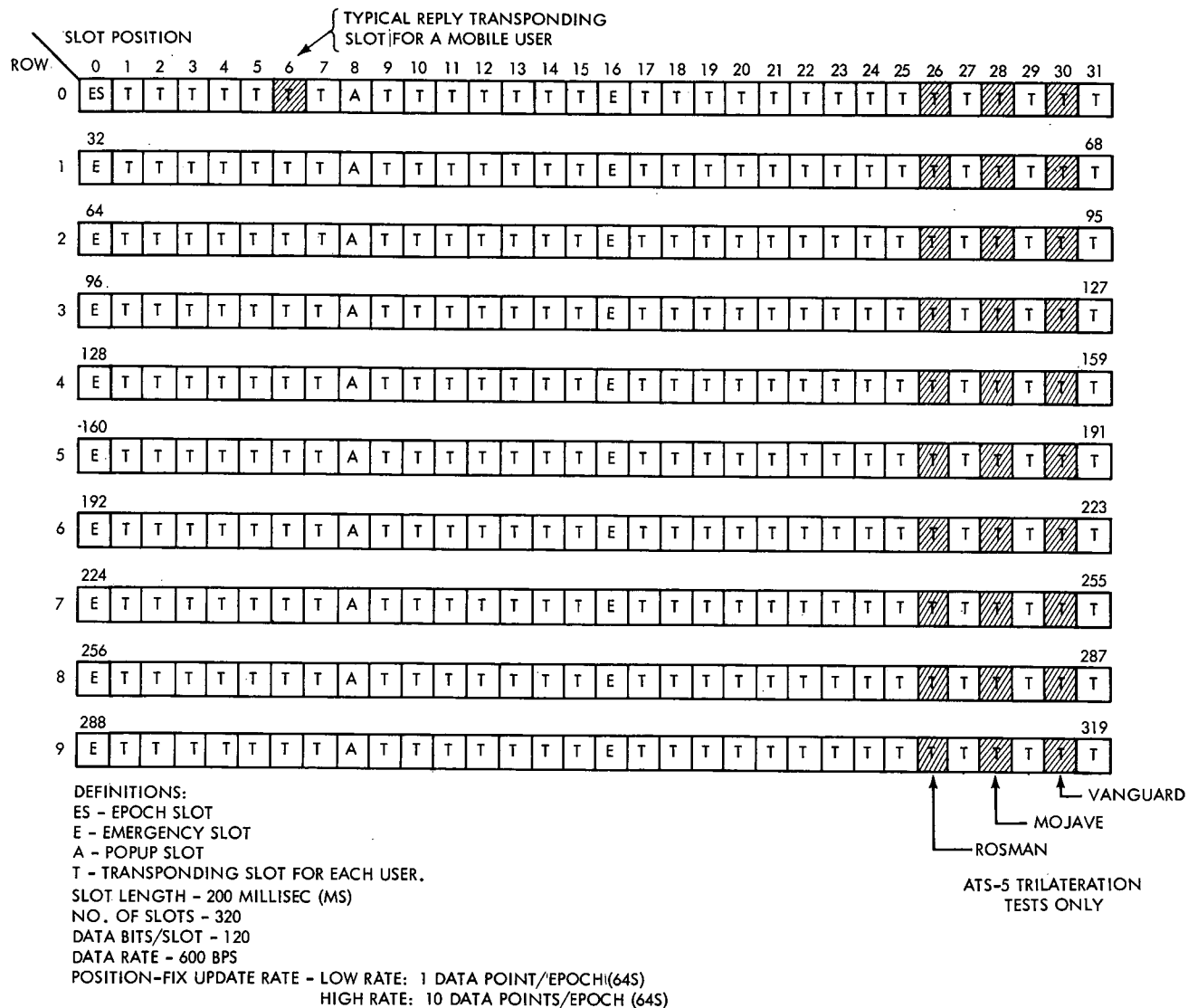
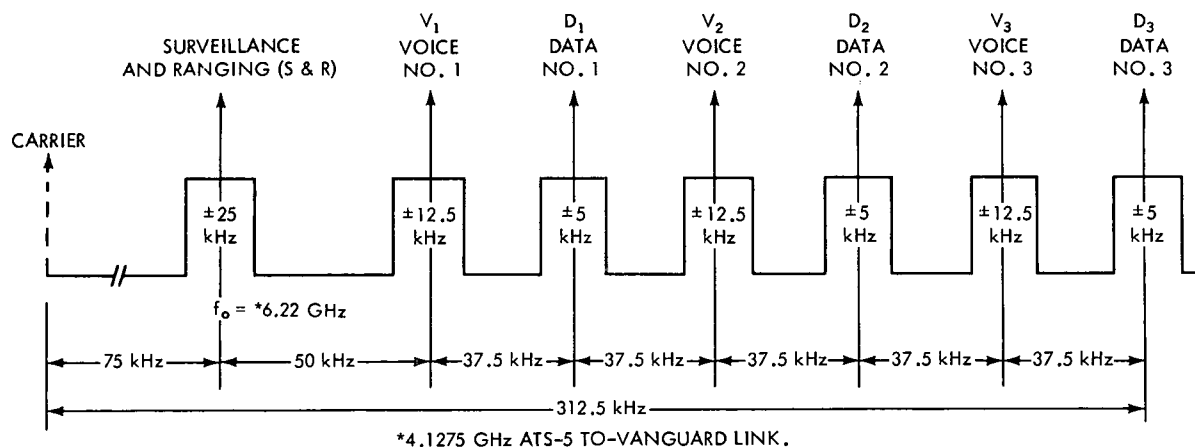
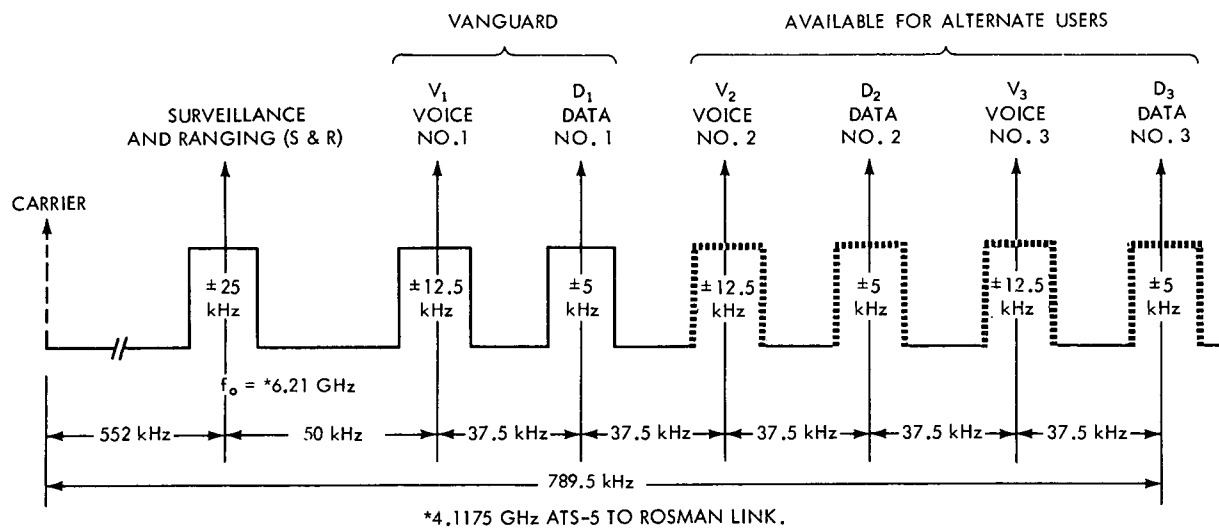


Figure 4. S&R Time-Division Multiplex Reply Matrix, Sea and Trilateration Tests, Vanguard Place Experiment.



(a) Typical Rosman Station-To-Spacecraft (ATS-5) -To-Vanguard Frequency Spectrum (SSB).



(b) Typical Vanguard-To-ATS-5 To-Rosman Station Frequency Spectrum (SSB).

Figure 5. Frequency Spectrum, Vanguard/Place Transmission Links  
Between Vanguard and Rosman Station

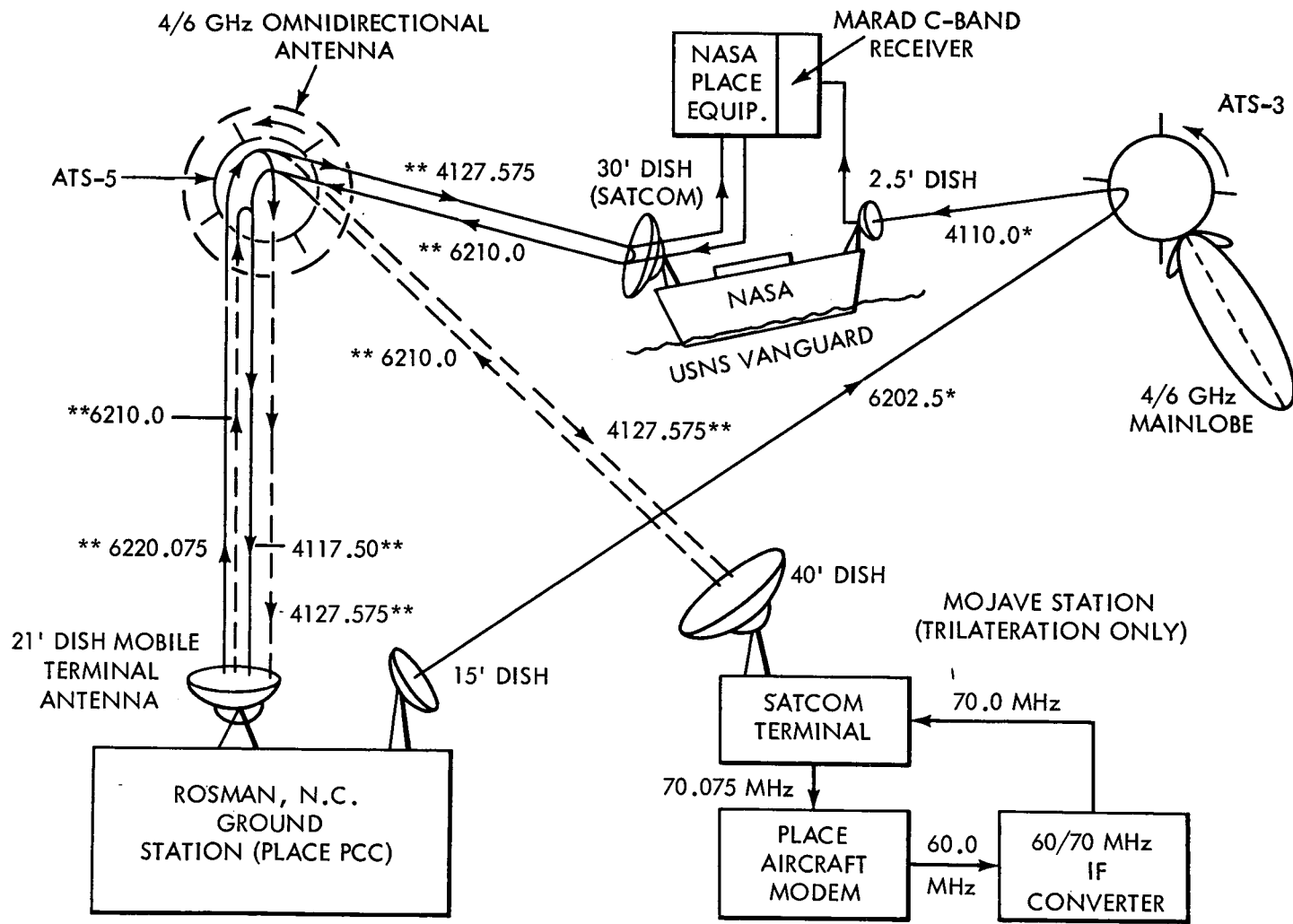


Figure 6. NASA-USNS Vanguard/Place Experiment at C-Band Using ATS-3 and ATS-5

Various characteristics for the ATS-5 and ATS-3 satellites, an ATS-5, C-Band Frequency Plan, and C-Band RF-Link Calculations are given in Appendix 1 (Tables 1-1 thru 1-4, Figure 1-1 and Figure 1-2). The weakest RF link is from ATS-3 to the Vanguard; however the peak value of 50.6 dB-Hz, Carrier-to-Noise Power Density,  $C/N_0$ , is sufficient for a viable PLACE experiment (Table 1-4). For a fully-loaded PLACE spectrum, the C-band links will operate at signals only several decibels above threshold.

The equipment configuration for the Rosman Station (Figure 2-1, Appendix 2), for the Vanguard/PLACE Sea Tests, contains both a 6 GHz and a 4-GHz RF link between Rosman and the ATS-3 satellite. The function of the 4-GHz RF link is to monitor transmissions from ATS-3 to insure that the narrow, 3 dB, beamwidth ( $0.7^\circ$ ) of the 15-ft. dish antenna is always pointing toward ATS-3, which drifts approximately  $\pm 3^\circ$  in latitude over a 24-hr. period, and to insure a constant frequency of 4.1100 GHz from ATS-3 to the Vanguard.

Vanguard/PLACE equipment for the Vanguard's Sea Tests is shown in Figure 2-2 (Appendix 2) which includes functional interconnections between the Vanguard's SATCOM system, NASA-PLACE equipment, and the MARAD, 2.5-ft, C-Band, Dish Antenna and C-Band Receiver.

The equipment configurations for the Rosman Station (Figure 2-3), for the Vanguard (Figure 2-4), and the Mojave Station (Figure 2-5) are shown in Appendix 2 for the Trilateration Tests, Vanguard/PLACE Experiment.

A major function of the Vanguard/PLACE Experiment is to compute the real-time position of the Vanguard, during the Sea Tests, with the "on-line" PDP 11/20 computer which is a part of the PLACE Control Center (PCC) at Rosman. The return ranging signals from the Vanguard to the Rosman computer are processed through the PLACE-Interface-Logic Unit (ILU) which takes the two sequential replies and calculates the two ranges through the satellites (ATS-5 and ATS-3). A typical format of the Rosman-PLACE, PGE/PCC, line printer (real-time) printout (Table 2) includes the roundtrip range to Satellite 1 (ATS-5) and roundtrip range to Satellite 2 (ATS-3).

The real-time position of the Vanguard will be computed by the Rosman PLACE system with an accuracy better than  $\pm 1$  n. mi., the PLACE instrumentation capability. NASA-derived ephemeris data from both satellites will be entered into the computer, appropriate for the time period covering each particular test. The Vanguard's, on-board, "truth", navigation systems will provide an averaged position of the ship within  $\pm 0.1$  n. mi. which will be compared to the ship's position as determined by the NASA-PLACE system.

### III. VANGUARD/PLACE EXPERIMENT TEST SCHEDULE

The Vanguard/PLACE Experiment will be conducted while the Vanguard is at sea, en route to the PIONEER Test Support Position (TSP) from Port Canaveral, Florida, and during the sailing time from the PIONEER TSP, while en route to Mar Del Plata, Argentina. There are approximately eight sailing days from Port Canaveral to PIONEER TSP; whereas an additional 9 or 10 days are required for the voyage from PIONEER TSP to Argentina (Figure 7).

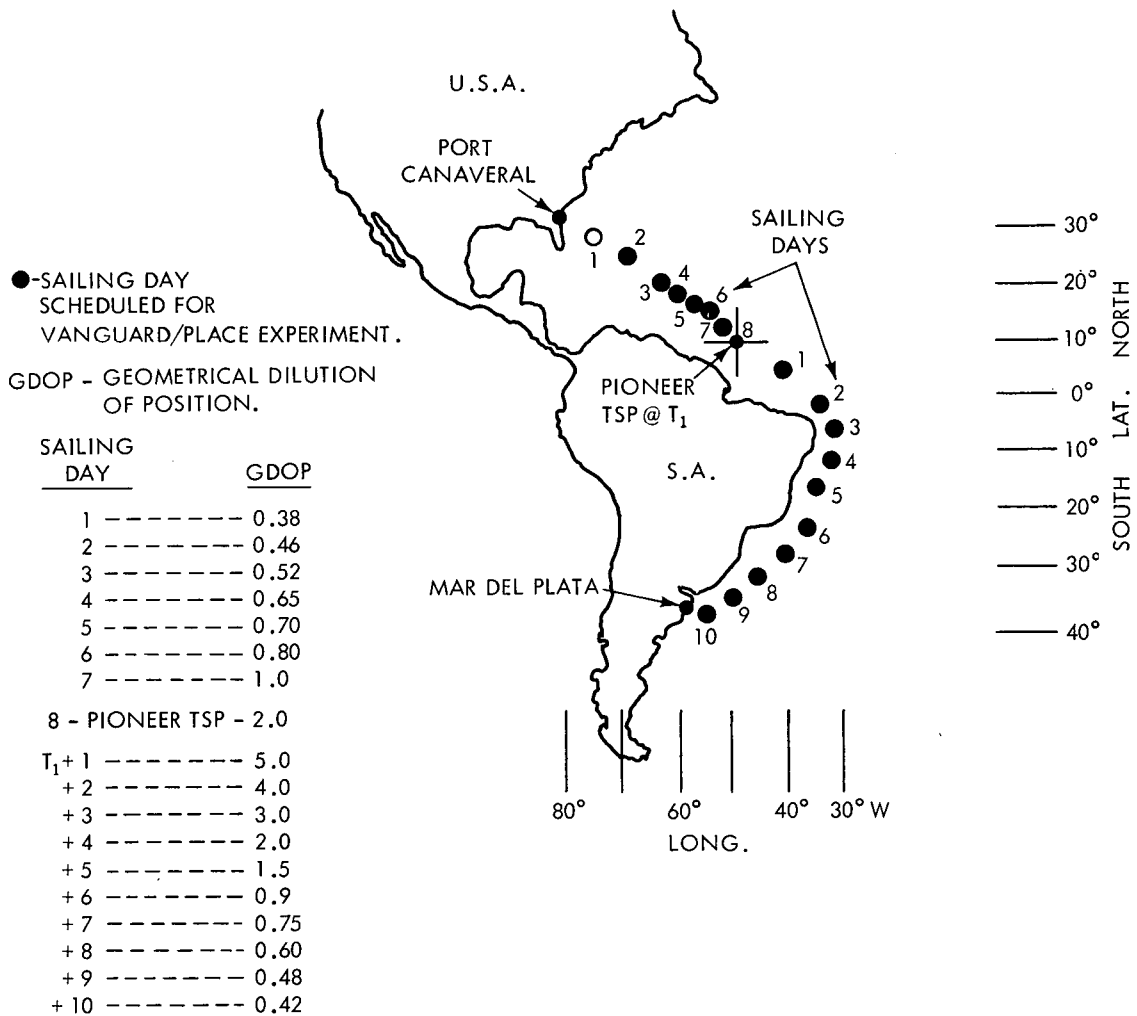


Figure 7. Vanguard Route, Sea Tests, Vanguard-Place Experiment

The Vanguard's voyage extends over both northerly and southerly latitudes, providing an excellent opportunity to measure GDOP (geometrical dilution of position) for the PLACE system. GDOP is a measure of the user's-position-location error magnification; a GDOP of "one" results in an error in position of one standard deviation. Maximum values of GDOP occur near the equator ( $0^{\circ}$  latitude).

Considering satellite-support time for MARAD, and other U. S. Government agencies, Table 3-1 (Appendix 3) is a composite compilation of ATS-3/ATS-5 satellite support time expressed in Greenwich Mean Time (GMT), or Zulu time, for the NASA/Vanguard/PLACE Experiment (Sea Tests). Table 3-1 includes weekend support time which accounts for the fact that 59.0 hours of ATS-3/ATS-5 satellite support time were allotted for the Vanguard/PLACE Experiment; an additional 9.5 hours of ATS-5 support time has been assigned, not accompanied by ATS-3 support time.

In the Experiment Test Plan, which follows, the ATS-3/ATS-5 satellite support time has been reserved mainly for Vanguard/PLACE position-location measurements, requiring both satellites; whereas the additional ATS-5 support time will be used for 2-way voice communications, 1200-bps data communication experiments, and single-satellite, 2-way, ranging measurements.

The ATS-5 satellite support time, required for the Vanguard/PLACE Trilateration Tests, in Table 3-2 (Appendix 3), is planned for May and June 1973.

#### IV. VANGUARD/PLACE EXPERIMENT INSTRUMENTATION, SEA TESTS

##### A. PLACE-System Instrumentation On-Board Vanguard

As mentioned earlier, it was necessary to fabricate a rack of PLACE hardware, over-and-above that PLACE hardware already committed for the ATS-F/PLACE Experiment, for installation on the Vanguard. The necessary Vanguard instrumentation, including the additional PLACE rack is shown in Figure 4-1, which indicates the interconnections with the Instrumentation-Recording System (FR-600 Recorder), the Vanguard's SATCOM Terminal and the on-board, C-band, receiving system (Reference 7) supplied by MARAD. A simplified system block diagram is shown in Figure 2-2, Appendix 2.

The complement of channel track assignments for the FR-600 recorder, for the Vanguard/PLACE Experiment on board equipment, is shown in Table 4-1, Appendix 4.

The Vanguard/PLACE equipment on the Vanguard relays 2-way ranging signals, 2-way voice communications, and 2-way data (1200 bps, High-Rate channel) communications back to the Rosman Station via the ATS-5 satellite. In addition, the Vanguard receives PLACE ranging signals, also originating at the Rosman Station, from ATS-3; these ranging signals are in turn relayed back to the Rosman Station, via the Vanguard's SATCOM Terminal, and the ATS-5 satellite.

The PLACE ranging signals received from the ATS-5 and ATS-3 satellites are transmitted back to the Rosman Station, via ATS-5, in appropriate time slots within the time-division-multiplex (TDM) matrix (see Figure 4) for the PLACE Surveillance and Ranging (S and R) channel.

#### B. PLACE-System Instrumentation at Rosman Station

The PLACE system located at the Rosman Station originates 2-way ranging signals, 2-way voice communications, and 2-way data (1200 bps, High-Rate channel) communications for transmission to the Vanguard's SATCOM Terminal via the ATS-5 satellite. A 21-ft-dish antenna (Mobile Terminal), located at the Rosman Station, is utilized for this purpose.

In addition, the PLACE system originates a second Range-Tone Set, containing 3 range tones, Figure 3(b), for transmission to the ATS-3 satellite via a 15-ft-dish antenna terminal (Figure 4-2, Appendix 4), also located at the Rosman Station.

The PLACE system (Figure 4-2, Appendix 4) contains an "on-line" PDP-11/20 computer, including a Central-Processor Unit (CPU), a DEC writer, Master and Slave Tape Units, and a 132-column-wide Line Printer.

The PDP-11/20 computer calculates in real time (on line with a Kalman-type filter) the position of the Vanguard, during the Sea Tests, in terms of latitude and longitude coordinates according to the format shown in Table 2. Satellite, a priori, ephemeris data, for both the ATS-5 and ATS-3 satellites, is inputted to the PDP-11/20 computer from a magnetic tape whose source data originated from the NASA-Range and Range Rate (RARR) system (see Table 3-1, Appendix 3, for RARR schedule).

An updated position of the Vanguard is computed "off line", from recordings of ranges from the PDP-11/20 Tape Units (Figure 4-2, Appendix 4), at a time when "updated" (post-measurement) RARR data becomes available for the ATS-5 and ATS-3 satellites.

An Audio Tape Recorder is contained within the PLACE system at the Rosman Station for transmitting and receiving voice communications with a similar Audio Tape Recorder (Figure 4-1, Appendix 4) on board the Vanguard.

Two-way, data communication (1200 bps High-Rate, HR, channel) is maintained between the Vanguard and the Rosman Station by means of a Frederick 600 Data Test Set, located both on board the Vanguard and at Rosman (Figures 4-1 and 4-2, respectively, Appendix 4). The performance of the 1200-bps data channel is determined from measurements of carrier-to-noise power density ( $C/N_0$ ) and bit error rates measured by the Frederick 600 Data Test Set. In addition, raw 1200 bps data signals, and a 1200 bps clock signal, are recorded both on the Vanguard, and at Rosman, for playback later.

The complement of channel track assignments for the FR-600 instrumentation recorders are shown in Table 4-1 and Table 4-2, Appendix 4, which includes a channel containing raw bit-error pulses from the Frederick 600, used for determining bit-error rates in the 1200 bps data channel.

#### C. VHF Backup Link Using ATS-3

The primary purpose of the VHF Backup Link is to provide an emergency backup link, as an option, for the Rosman C-band link to ATS-3, the second satellite. Appendix 5 describes the VHF Backup Link, and includes an RF-link calculation, which utilizes the omnidirectional, VHF, transmit/receive antenna on the ATS-3 satellite (Table 5-1).

### V. VANGUARD/PLACE EXPERIMENT TEST PLAN, SEA TESTS

#### A. Operations - Readiness Tests

The primary purpose of the operations-readiness tests (ORT) is to determine the operational status of the Rosman station and the NASA/PLACE equipment on the Vanguard, including the MARAD C-band equipment (i.e., 2.5-ft-dish antenna, and C-band receiver) employed for receiving PLACE-ranging signals from the ATS-3 satellite, prior to the departure of the Vanguard from its docked position at Port Canaveral, Florida.

The ORT-test phase utilizes the satellites and ground terminals. The three operational modes (Modes A, B & C) for the ATS-3 and ATS-5 satellites, at both C-band and VHF, are given in Table 6-1 which includes six station configurations (1 thru 6) for the Vanguard and Rosman terminals.

As listed in Table 3-1, Appendix 3, the ORT-test schedule begins on March 5, 1973, and extends through March 26, 1973; Table 6-2, Appendix 6, lists detailed PLACE equipment checkout tests scheduled for the ORT-test phase.

#### B. Sea-Test Scenario

The most significant part of the Vanguard/PLACE experiment is the Sea-Test Phase. Primary emphasis will be given to the PLACE, sidetone, ranging measurements, through the ATS-5 and ATS-3 satellites, in turn utilized to compute the position location of the Vanguard; the sea-test scenario (Appendix 7, Table 7-1) was structured to this end.

Whereas ranging through two satellites produces two independent line-of-positions (LOP) for locating the ship, two-way ranging through only one satellite (ATS-5) produces a single LOP, which when combined a single earth coordinate (e.g., ship's latitude from on-board navigation systems), also produces useful information for position fixing the ship.

Ordinarily, the geometrical dilution of position (GDOP) for a single LOP degrades when the user is positioned in equatorial regions, for a synchronous equatorial satellite. However, for the Vanguard Sea Tests the degraded accuracy affects only one earth coordinate (i.e., latitude in the case of the ATS-5 satellite positioned at 105° W, and the Vanguard's route over the equator, Figure 7), whereas the accuracy of the remaining coordinate (ship's longitude) is unaffected.

Therefore, an excellent position fix for the ship can be obtained at all times from a single LOP measurement, by means of two-way ranging through ATS-5, when combined with the ship's latitude derived from the on-board navigation systems. Such a position fix, for the Vanguard, will be computed (off line) for each ranging measurement point. The utilization of a single LOP, combined with a single earth coordinate passing through the Vanguard, increases the effective-satellite support time for ship position-location statistics.

Secondary emphasis will be placed upon two-way, voice, communication measurements (i.e., ship-to-shore and shore-to-ship) between the Vanguard and Rosman terminals. Voice tests will be conducted for at least 18 hours (Appendix 8, Tables 8-1 and 8-2).

Five voice-test tapes have been prepared for voice transmissions (Appendix 8, Table 8-2), which include typical maritime and air-traffic-control messages. As a part of voice testing, a telephone-network free-conversation test has been planned, at which time personnel on the Vanguard will contact parties in the continental United States; an appropriate rating sheet will be prepared by participating personnel (Table 8-3, Appendix 8).

A smaller percentage of time has been scheduled for the various, remaining, miscellaneous tests that are required to evaluate fully the PLACE system. These include two-way, 1200-bps (H-R), data communications testing, the measurement of intermodulation products, and the evaluation of the multiple-access capability of PLACE (Appendix 7, Table 7-1).

## VI. DATA REDUCTION AND ANALYSIS, VANGUARD/PLACE EXPERIMENT

The data reduction and analysis (DR&A) phase includes both "on line" and "off line" data processing. The primary data, of course, is the position-location information for the Vanguard, computed initially "on line" by the PLACE PDP-11/20 computer at Rosman (Appendix 4, Figure 4-2), from two-satellite, sidetone-ranging measurements. However, the Vanguard's position-location data will be updated later, "off line", as a part of the DR&A phase when updated ATS-3/-5 satellite-ephemeris data becomes available.

If all goes well, the following maximum amount of position-location data will be obtained from the Vanguard/PLACE experiment:

⊗ 2-Satellite LOP Measurements - - - - -	59.0 hours
⊗ 1-Satellite LOP Measurements - - - - -	9.5 hours
	<hr/>
*Total	68.5 hours

Assuming that all PLACE-ranging measurements will be made at the high rate of ten ranging points per minute, this results in 600 ranging points per hour, or a grand total of approximately 41,000 ranging points for the total 68.5 hours available.

It is envisioned that the position-location data will be plotted, in hourly increment sets, wherein each ranging point appears in a latitude/longitude-coordinate\*\* system along with a calibration curve of the Vanguard's true position obtained from on-board navigation systems. To further aid the analysis, an rms-position error will be computed for each hourly increment set of data, with GDOP computed for data sets.

The basic-source ranging data, used in the DR&A phase, will be derived from magnetic tapes recorded by the PLACE, TM-11A, Tape Units located at the Rosman terminal.

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\*Includes satellite/ground-station support over weekends.

\*\*Mercator projection chart giving latitude and longitude in equal distance.

The analysis of the voice tapes will be performed "off line", both by playback to a listening audience, and by playback to a computer. These tests will be classified as follows:

- (1) Live-Audience Analysis
  - Intelligibility Test (IT)
  - Modified-Rhyme Test (MRT)
  - Phonetically-Balanced Test (PBT)
- (2) Computer Analysis
  - Articulation Index (AI)
- (3) Free-Conversation Telephone Test

The voice test results including IT, MRT, PBT and AI will be plotted versus channel carrier-to-noise power density  $C/N_0$ , expressed in dB-Hz.

The analysis of the 1200-bps, H-R, data-channel tests will be performed "off line", both on data from the Frederick 600 Data Test Set, and from "raw" 1200-bps signals (and clock) recorded by the FR-600 tape recorder on the Vanguard (Appendix 4, Figure 4-1), and at the Rosman terminal (Figure 4-2). The objective is to obtain bit-error probability performance versus  $C/N_0$ .

The secondary source of data will come from the FR-600 tape recorder, both on the Vanguard and at Rosman, for the track inputs given in Tables 4-1, and 4-2, Appendix 4.

Analog strip-chart recordings will be made from magnetic tapes obtained from the FR-600 recorders, and these in turn analyzed during the DR&A phase. The following approximate quantities of magnetic tape (10" reel, 1-mil tape @ 3-3/4 in./s speed) will result from the Sea Tests:

● Vanguard FR-600 Tapes - - - - -	35 ea.
● Rosman FR-600 Tapes - - - - -	35 ea.
	<hr/>
Total (Approximately)	70 ea.

A strip-chart playback speed of 2 mm/s is suggested for data processing.

## VII. ATS-5 SATELLITE TRILATERATION TESTS

Satellite-ephemeris data for the ATS-3 and ATS-5 satellites is a necessary input to determine the position location of the Vanguard during the Sea-Test Phase. In effect, the satellite-ephemeris data provides the unknown value of the range from the Rosman station to the ATS-5 satellite, and similarly the range from Rosman to the ATS-3 satellite. Having provided both these ranges as a priori information (up-dated, post-measurement, ephemeris data is also satisfactory), the value of the range from ATS-5 to the Vanguard,  $R_1$ , and similarly the range from ATS-3 to the Vanguard,  $R_2$ , can be computed from the roundtrip range measurements made by the PLACE system at Rosman (Figure 2). Of course, after determining values for  $R_1$  and  $R_2$ , the position location of the Vanguard can then be computed.

Therefore, to determine the ranges  $R_1$  and  $R_2$  requires a knowledge of the satellite's position for the Vanguard/PLACE Experiment. However, in the forthcoming ATS-F/PLACE Experiment, the satellite's position will be determined independently of external data. To accomplish this, the satellite's position will be determined by a geometrical-trilateration method by placing a transponder at each of three known station locations, and performing sidetone-ranging measurements. Satellite trilateration tests, for the ATS-5 satellite, will be performed in the Vanguard/PLACE Experiment for station locations shown in Figure 9-1, Appendix 9.

The unique location of the Vanguard, while docked at Mar Del Plata, Argentina, provides unusually long baselines with the Rosman, N. C. and Mojave, California stations for accurate trilateration measurements with the ATS-5 satellite. Since the ATS-5 satellite has a rather stable orbit, the trilateration tests from the Vanguard/PLACE Experiment should provide an excellent data base for updating ATS-5 ephemeris data.

The necessary trilateration equations for computing the dynamic, geocentric coordinates for the ATS-5 satellite, as well as the corresponding ranges  $r_1$ ,  $r_2$  and  $r_3$  (Figure 9-1, Appendix 9) from the three ground terminals, is included in Appendix 9 (private communication, Reference 8, received from the Bell Aerospace Company). These equations are based upon the assumption of random motion of the satellite, rather than knowledge of satellite orbital motion. (i.e., orbital elements).

Necessary inputs for trilateration computations include the locations of the three ground stations, within an accuracy of about 15 m, as well as the measured roundtrip ranges from the Rosman station to the Vanguard and Mojave stations, through the ATS-5 satellite.

A Kalman-type filter is used for the computations: H. Winter (Reference 8) provided a typical case shown in Table 9-1, Appendix 9, for the ATS-5 satellite located approximately at 105°W. longitude. The data rate is assumed as one ranging measurement per minute; however, the Vanguard/PLACE Trilateration Tests will be conducted at the higher update rate of ten ranging measurements per minute for greater accuracy.

In closing, a series of trilateration tests with the ATS-5 satellite have been proposed (Table 3-2, Appendix 3), which include PLACE, sidetone-ranging measurements extending over a 24-hour interval.

At the suggestion of Mr. Roy E. Anderson, General Electric Company, Corporate Research and Development, Schenectady, New York, the Vanguard/PLACE Trilateration Tests will be conducted concurrently, and compared with, trilateration tests on ATS-5 to be jointly conducted by the General Electric Company (GE). Reference 9 describes GE's method for making satellite trilateration measurements at VHF and L-band frequencies.

Certain limitations in ground station and spacecraft resources are outlined as follows. First, the ATS-5 satellite does not contain a VHF-relay transponder, but does have an L-band transponder. Second, only one of the General Electric stations (Radio-Optical Observatory, Schenectady, N. Y.) has L-band capability. Finally, spacecraft primary-power considerations restrict L-band transmissions from the ATS-5 satellite to 10 minutes per hour, maximum, when operating over a 24-hour interval; continuous operation may extend up to several hours, if then terminated. However, both the C-band and L-band transponders in ATS-5 may be operated simultaneously, with the C-band transponder operating continuously for 24 hours if desired.

A joint NASA/GE trilateration experiment is outlined as follows. First, compute (on line) ATS-5's latitude/longitude and altitude (distance from geocenter) coordinates vs GMT, at C-band, by means of the three NASA/PLACE trilateration stations located at Rosman, N. C., Mojave, California, and Mar Del Plata, Argentina (Vanguard). Second, conduct simultaneously with the C-band experiment 2-way ranging measurements, at L-band, between ATS-5 and GE's Radio-Optical Observatory, Schenectady, N. Y. Third, for the same time interval, recompute (off line) the latitude/longitude and altitude coordinates of the ATS-5 satellite using C-band data for two of the NASA/PLACE trilateration stations (e.g., Mojave and Vanguard), but substituting GE's ranging measurements, at L-band, taken by the Radio-Optical Observatory, Schenectady, N. Y., for the third station (e.g., in lieu of Rosman station). Various other combinations of stations could be tried, resulting in a direct comparison of L-band and C-band performance, with the larger error being attributed to L-band performance.

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## APPENDIX 1

### ATS-3 AND ATS-5 CHARACTERISTICS, C-BAND FREQUENCY PLAN, AND RF-LINK BUDGET CALCULATIONS

Table 1-1  
ATS-5 and ATS-3 Satellite C-Band Transponder Characteristics

CHARACTERISTIC \ TRANSPONDER	ATS-3		ATS-5	
	#1		#1	
	1	2	1	2
Antenna Polarization	Linear		Linear	
*Transmit Antenna Gain, dB	16.2		16.7	
*Receive Antenna Gain, dB	16.2		16.3	
Effective Radiated Power (ERP), dBw	22.2	24.6	21.4	24.4
TWT Power, Watts	4	8	4	8
Transmit Network Loss, dB	0	-.6	-1.3	-1.3
Antenna Noise Temperature, °K	290		290	
Receiver Noise Temperature, °K	890		890	
Receiver Noise Figure, dB	6.1		6.1	
Receive Effective Noise Temp, °K	1183		1183	
Receiver Network Loss, dB	-0.4		-0.4	
Uplink Frequency, MHz**	6212.094		6212.094	
Uplink Space Loss, dB	-199.8		-199.9	
Downlink Frequency, MHz**	4119.599		4119.599	
Downlink Space Loss, dB	-196.2		-196.3	

\*OMNIDIRECTIONAL antenna (ATS-5 only) has 1.3 dB gain, above isotropic.

\*\*Band Center of 25 MHz passband (Frequency Translation, FT Mode).

Table 1-2  
ATS-5 Link Budget  
30-Foot SATCOM Receive Antenna on Board Ship  
USNS VANGUARD  
21-Foot Transmit Antenna at Rosman

Parameter	Rosman to ATS-5 to Ship	
	6-GHz Up Link	4-GHz Down Link
Transmit Antenna Gain (dB)	48.5	1.3
Transmit Network Loss (dB)	- 1.0	- 0.4
Transmitter Power Out (dBW)	34.8	6.0*
ERP (dBW)	82.3	6.9
Receive Antenna Gain (dB)	1.3	48.0
Receive Network Loss (dB)	- 0.4	- 0.2
Free Space Loss (dB)	-199.9	-196.3
Atmospheric Loss (dB)	- 0.2	- 0.2
Polarization Loss (dB)	- 0.8	- 3.8
S/C Antenna Point Loss (dB)	- 0.5	- 0.5
Ground Antenna Point Loss (dB)	- 0.2	- 1.0
Net Propagation Loss (dB)	-201.6	-201.8
S/C Modulation Loss (dB)	-	- 3.5
Received Carrier Power (dBW)	-118.4	-150.6
Receive Effective Noise Temperature (°K)	1183	100
Receive Antenna Noise Temperature (°K)	(290)	
Noise Power Density (dBW/Hz)	-197.9	-208.6
Carrier/Noise Power Density $C/N_0$ (dB-Hz)	79.5	58.0

\* Two TWT's are used on ATS-5 for total of 8-watts (9.0 dBw); however, assume two equal-level signals which power share the repeater output power.

Table 1-3  
ATS-5 Link Budget  
30-Foot Transmit Antenna on Board Ship  
USNS VANGUARD  
21-Foot Receive Antenna at Rosman

Parameter	Ship to ATS-5 to Rosman	
	6-GHz Up Link	4-GHz Down Link
Transmit Antenna Gain (dB)	52.0	1.3
Transmit Network Loss (dB)	- 0.5	- 0.4
Transmitter Power Out (dBW)	35.0	6.0*
ERP (dBW)	86.5	6.9
Receive Antenna Gain (dB)	1.3	45.0
Receive Network Loss (dB)	- 0.4	- 0.4
Free Space Loss (dB)	-199.9	-196.3
Atmospheric Loss (dB)	- 0.2	- 0.2
Polarization Loss (dB)	- 3.8	- 3.8
S/C Antenna Point Loss (dB)	- 0.5	- 0.5
Ground Antenna Point Loss (dB)	- 0.2	- 1.0
Net Propagation Loss (dB)	-204.6	-202.0
S/C Modulation Loss (dB)	-	- 3.0
Received Carrier Power (dBW)	-117.2	-153.5
Receive Effective Noise Temperature ( $^{\circ}$ K)	1183	135
Receive Antenna Noise Temperature ( $^{\circ}$ K)	(290)	
Noise Power Density (dBW/Hz)	-197.9	-207.3
Carrier/Noise Power Density, $C/N_0$ (dB-Hz)	80.7	53.8**

\* Two TWT's are used on ATS-5 for total of 8-watts (9.0 dBW); however, assume two equal-level signals which power share the repeater output power.

\*\* 53.8 dB-Hz is minimum  $C/N_0$  required (see Reference 6, pp. III-78, -79 & 82) for transmitting a fully-loaded PLACE spectrum consisting of S and R channel (600 bps data and 4 range tones), 3 voice channels, and 3 high-rate (1200bps) data channels (Frequency-Translation Mode). Thresholds for individual channels in the composite signal are defined as:

S and R ..... 42 dB-Hz  
HR (1200 bps) Data ..... 42 dB-Hz  
Voice ..... 46 dB-Hz.

Table 1-4  
ATS-3 Link Budget (#1 Transponder)  
15-Foot Transmit Antenna at Rosman  
2.5-Foot Receive Antenna on Board Ship  
USNS VANGUARD

Parameter	Rosman to ATS-3 to Ship	
	6-GHz Up Link	4-GHz Down Link
Transmit Antenna Gain (dB)	46.0	16.2
Transmit Network Loss (dB)	- 0.5	- 0.5
Transmitter Power Out (dBW)	24.8*	9.0
ERP (dBW)	70.3	24.7
Receive Antenna Gain (dB)	16.2	27.3
Receive Network Loss (dB)	- 0.4	- 1.0
Free Space Loss (dB)	-200.0	-196.5
Atmospheric Loss (dB)	- 0.2	- 0.2
Polarization Loss (dB)	- 0.8	- 3.0
S/C Antenna Point Loss (dB)	- 0.5	- 0.5
Ground Antenna Point Loss (dB)	- 0.2	- 1.0
Net Propagation Loss (dB)	-201.7	-201.2
S/C Modulation Loss (dB)	-	- 3.0
Received Carrier Power (dBW)	-115.6	-153.2
Receive Effective Noise Temperature (°K)	1183	300
Receive Antenna Noise Temperature (°K)	(290)	(100)
Noise Power Density (dBW/Hz)	-197.9	-203.8
Carrier/Noise Power Density $C/N_0$ (dB-Hz)	82.3	** 50.6 Peak)

\*Assumes 300 watts, minimum, total power; however, GE's TRANSATEL Terminal provides a nominal power of 2.5 kW.

\*\*Reduces to 47.6 dB-Hz at the 3dB-down point on the ATS-3 antenna pattern. For a modulation phase deviation of 1 radian rms, each of 3 range tone sidebands are down 5.3 dB below total signal power, resulting in  $C/N_0 = 42.3$  dB-Hz (42 dB-Hz threshold, see Table 1-3).

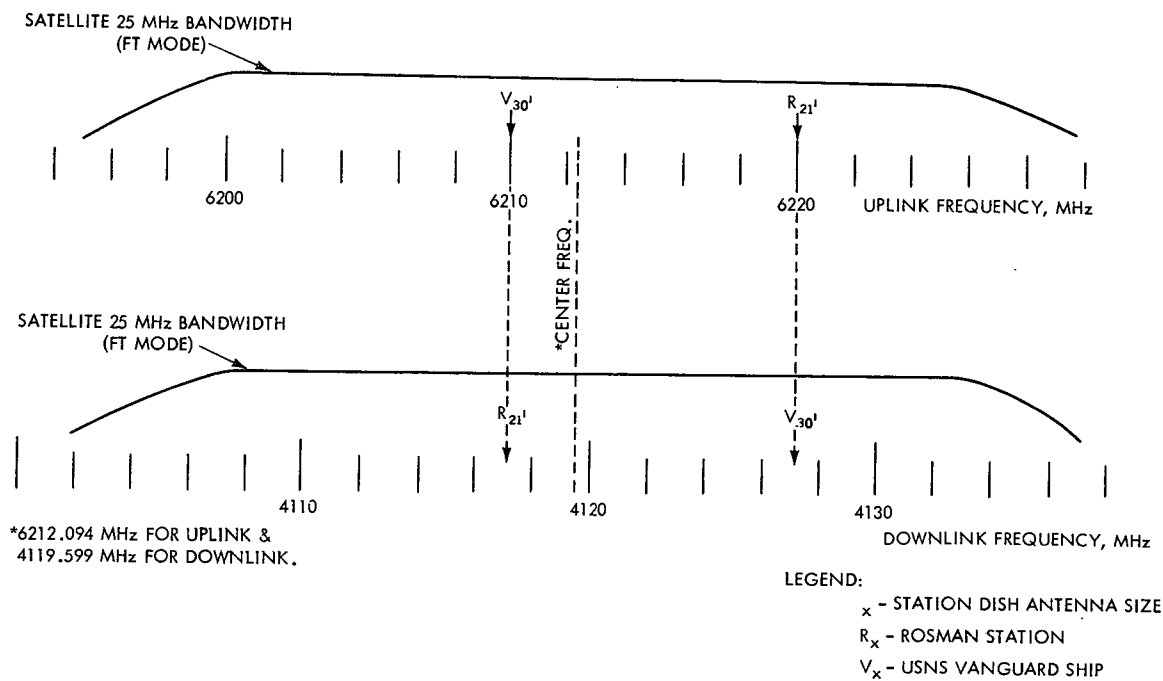


Figure 1-1. ATS-5 Frequency Plan for Vanguard/Place Experiment

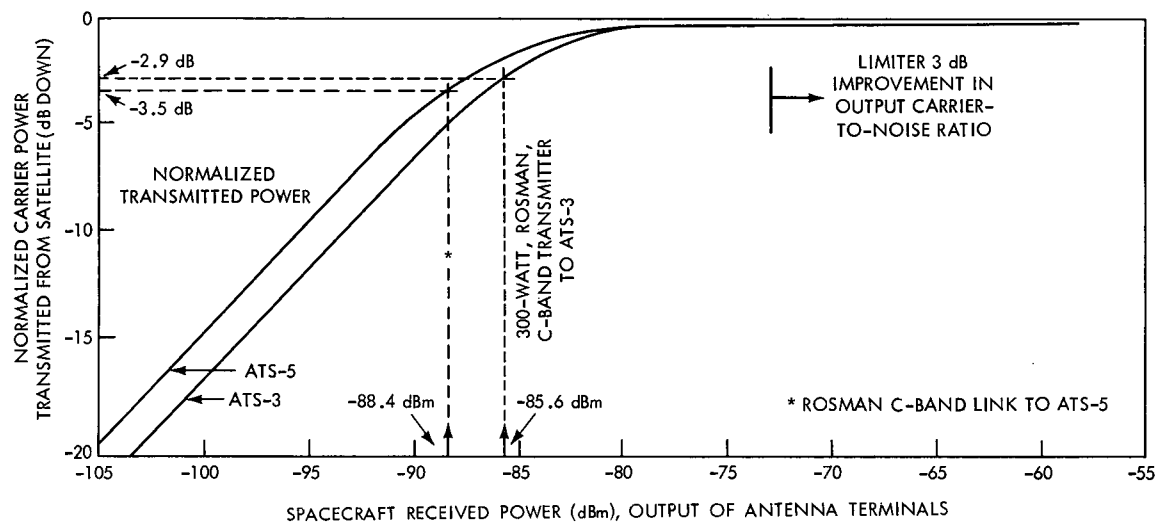


Figure 1-2. Transponder Saturation Characteristics for ATS-3 and ATS-5 Satellites

## APPENDIX 2

ROSMAN AND VANGUARD EQUIPMENT CONFIGURATIONS,

VANGUARD/PLACE SEA TESTS;

ROSMAN, VANGUARD AND MOJAVE CONFIGURATIONS,

ATS-5 TRILATERATION TESTS

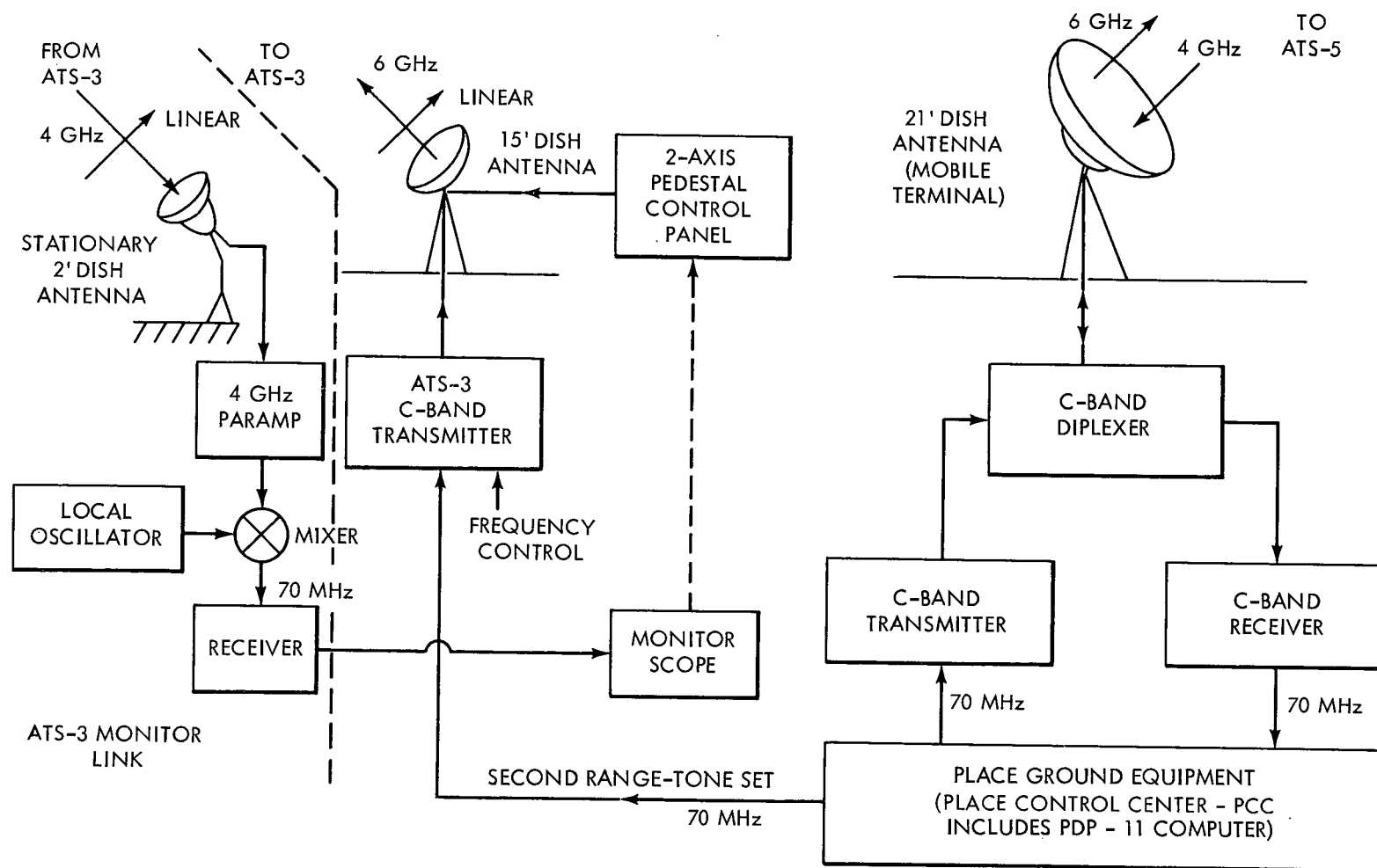


Figure 2-1. Rosman Station Equipment Configuration, Vanguard/Place Experiment, Sea Tests

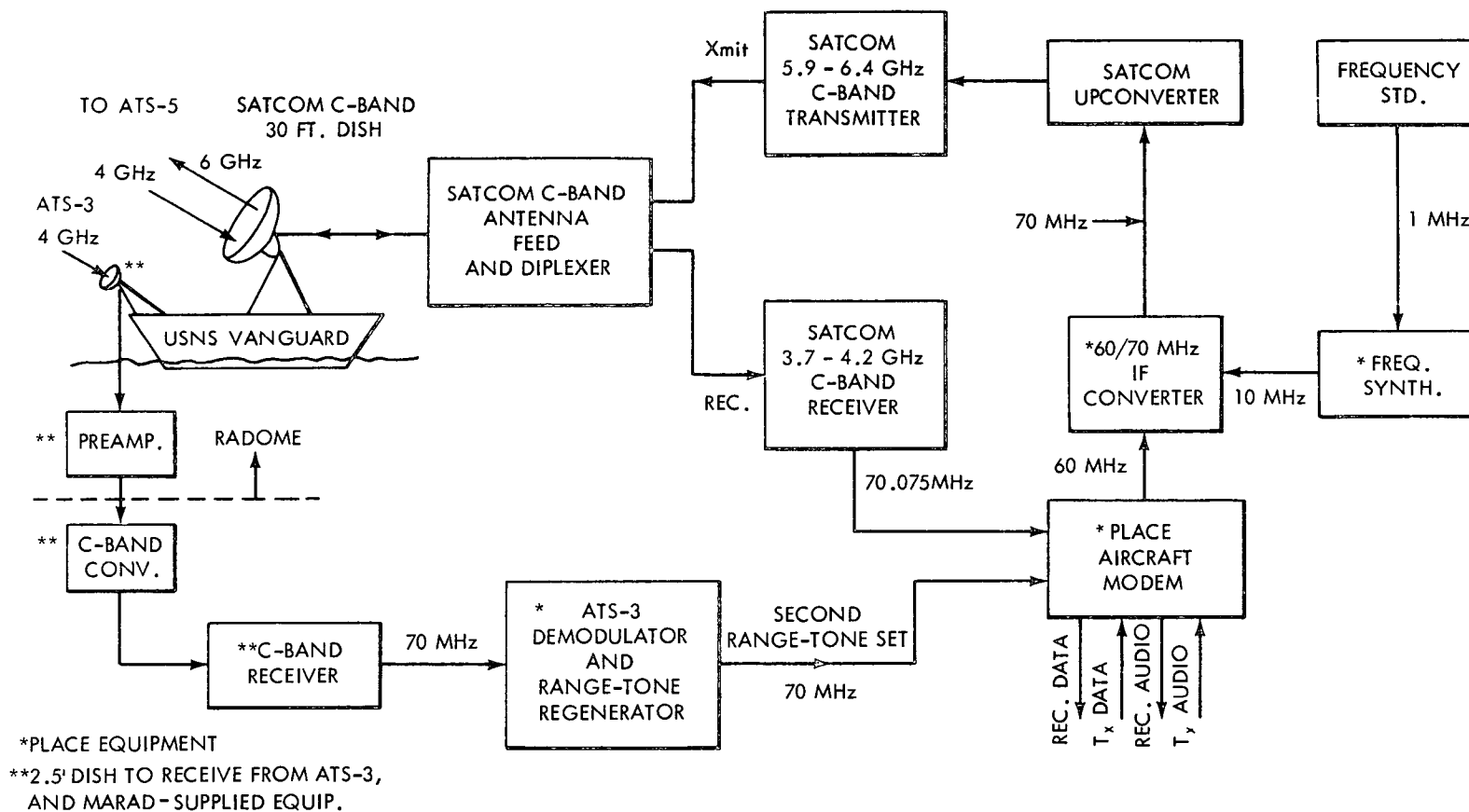


Figure 2-2. Vanguard/Place Equipment for USNS Vanguard, Sea Tests

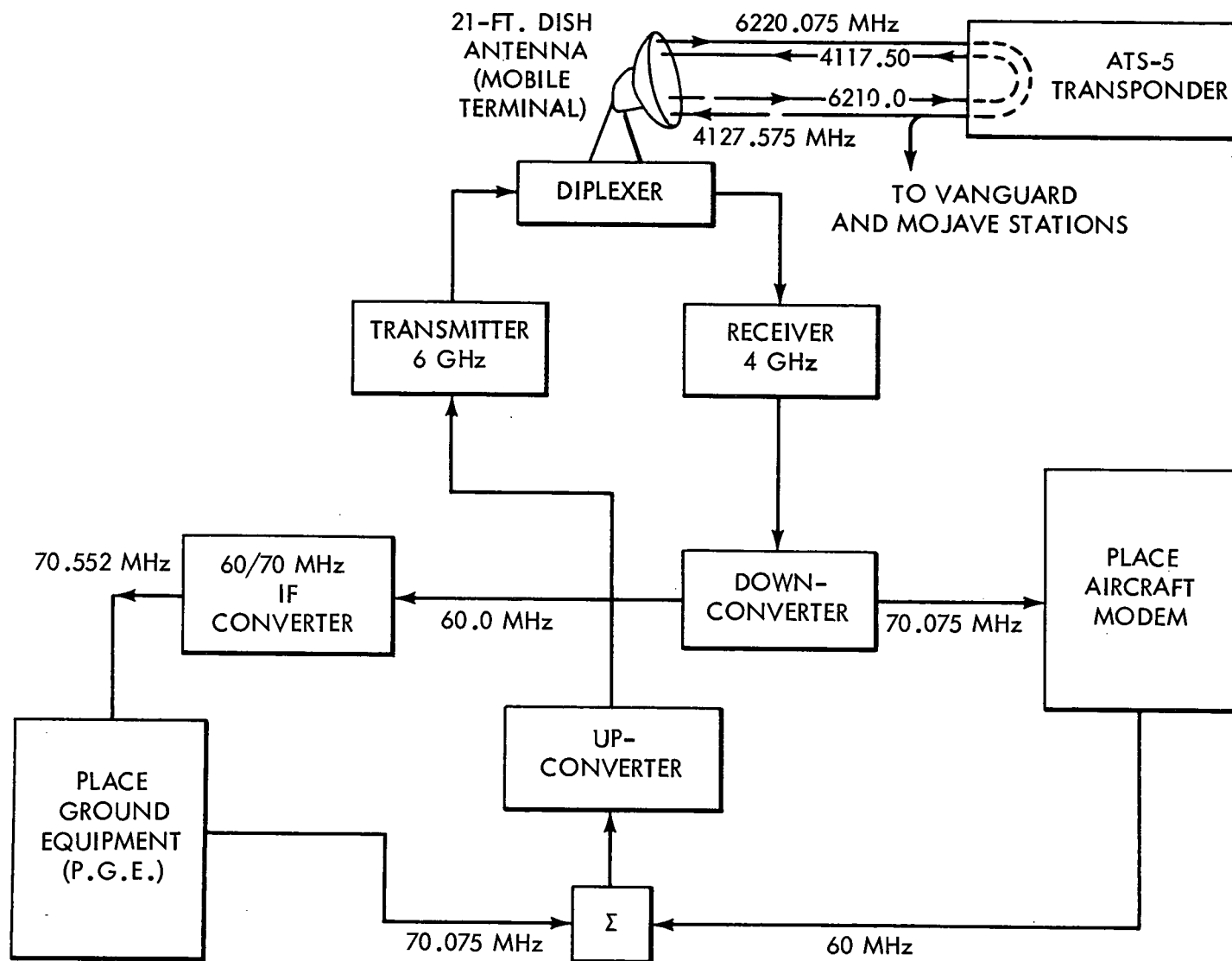


Figure 2-3. Rosman Equipment Configuration, ATS-5 Trilateration Tests, Vanguard/Place Experiment

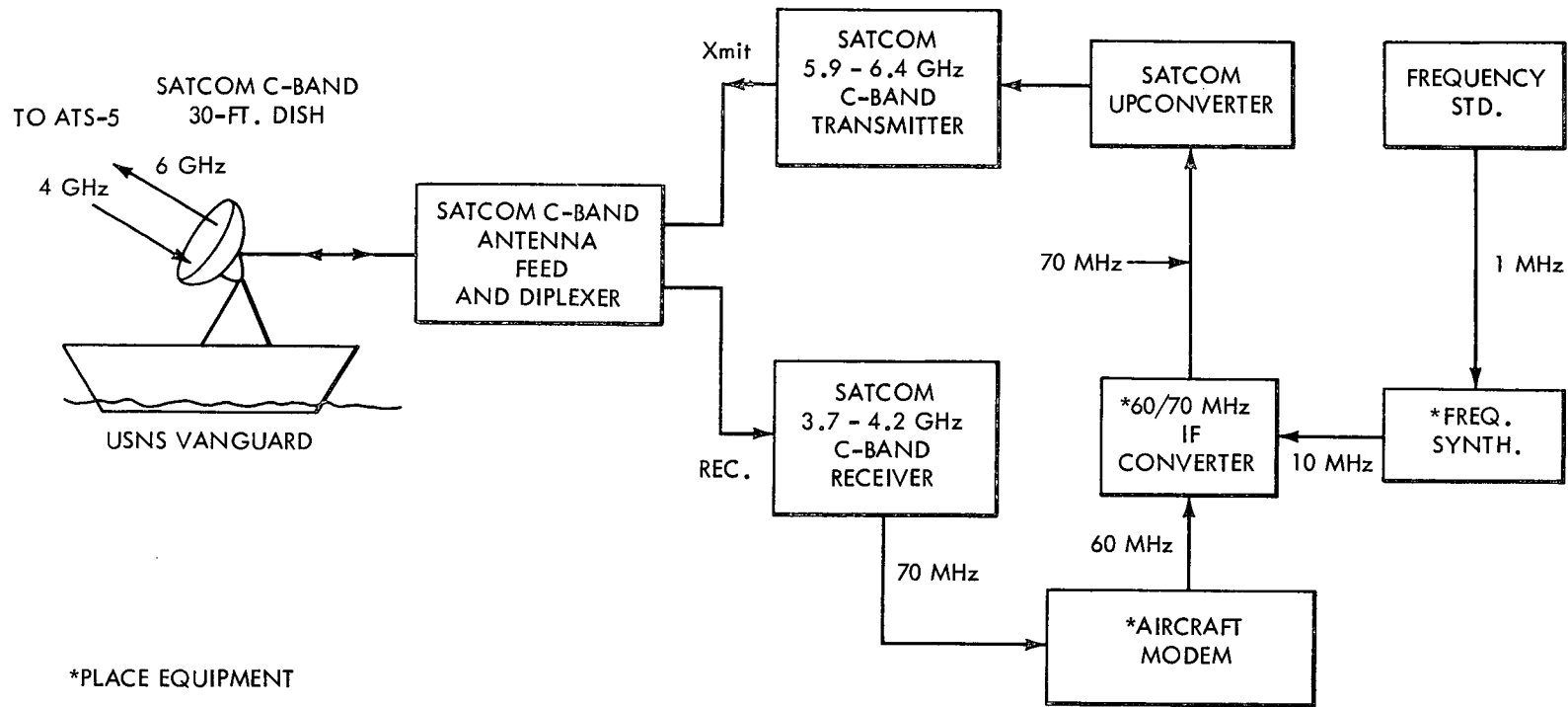


Figure 2-4. Vanguard Equipment Configuration, ATS-5 Trilateration Tests, Vanguard/Place Experiment

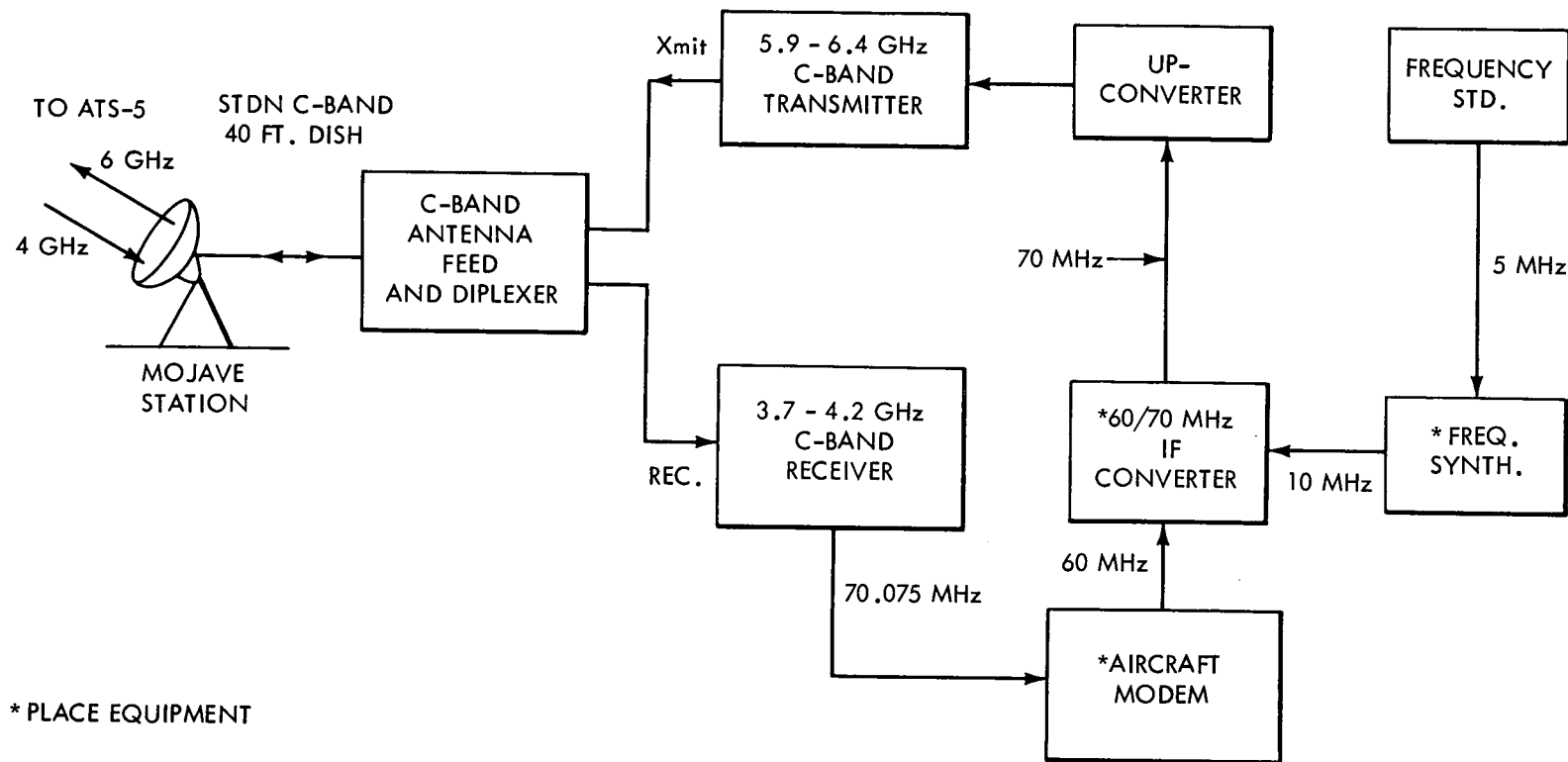


Figure 2-5. Mojave Equipment Configuration, ATS-5 Trilateration Tests, Vanguard/Place Experiment

## APPENDIX 3

VANGUARD/PLACE, ATS-3/-5, SATELLITE-SUPPORT  
TIME, SEA TESTS; ATS-5 SUPPORT TIME,  
TRILATERATION TESTS

Table 3-1  
Vanguard/PLACE Experiment, ATS-3/ATS-5 Satellite - Support Time (GMT), Sea Tests

	Zulu Day	March 1973	Vanguard		NOAA (ATS-3)	FAA (ATS-5)	MARAD	NASA/PLACE		RARR**	Zulu Day
			Pioneer	Skylab			ATS-3 & ATS-5	ATS-3 & ATS-5	ATS-5		
	1				1050Z-2230Z		0000Z-0100Z; 1700-2400				1
	2				(each day except as noted)		(each weekday except RARR days and as noted)				2
Sat.	3										3
Sun.	4										4
	5	NASA/MARAD Operations-Readiness Testing @ Port Canaveral, Fla.					1600Z - 2330Z	2330-2400: 0.5 Hr.			5
	6						1800Z - 2330Z	0000-0330: } 4.5 Hr.			6
	7					0100-0300		2300-2400: } 1.5 Hr.	0300-0530		7
	8							0000-0100: } 1.5 Hr.		1700-2400	8
	9							0000-0130: 1.5 Hr.		1600-2400	9
Sat.	10									0000-0700	10
Sun.	11										11
	12						2230Z - 2330Z	2330-2400: 0.5 Hr.			12
	13					0100-0300	2230Z - 2400Z	0000-2345: 3.75 Hr.	0345-0530		13
	14						1600Z - 0100Z	0100-0345: 2.75 Hr.			14
	15						1600Z - 0100Z	0100-0345: 2.75 Hr.			15
	16						1700Z - 0100Z	0100-0345: 2.75 Hr.			16
Sat.	17					2000-2330		0100-0345: 2.75 Hr.			17
Sun.	18					2030-2400					18
	19						1830Z - 2400Z				19
	20					0000-0330	1730Z - 2300Z	2300-2400: 1.0 Hr.	0330-0600		20
	21					0900-1100					21
	22							1.0 Hr.	0330-0600		22
	23							1.0 Hr.	0330-0600		23
Sat.	24							1.0 Hr.	0330-0600		24
	25	NASA-PLACE				{0000-0330} {0900-1100} {2100-2400}					25
Sun.	26	NASA-PLACE				{0000-0030} {2100-2400}		0030-0330: 3.0 Hr.			26
	27					0000-0030	1530Z - 1900Z	0030-0330: 3.0 Hr.		1700-2400	27
	28	Vanguard Departs				0000-0345	2245Z - 0200Z			{0000-0700} {1600-2400}	28/0
	29	Pioneer-G Simulation Tests	1200Z to 1200Z			{0000-0345} {2330-2400}	1700Z - 2330Z			0000-0700	29/1
	30					{0000-0300} {2330-2400}	1700Z - 2330Z				30/2
Sat.	31	NASA-PLACE				0000-0300	1600Z - 1900Z	2330-2400; 0.5 Hr.			31/3
								0000-0400: } 7.0 Hr.	0400-0530		
								2100-2400: }			

Sailing Days from Port Canaveral

Table 3-1 (Continued)  
Vanguard/PLACE Experiment, ATS-3/ATS-5 Satellite - Support Time (GMT), Sea Tests

	Zulu Day	April 1973	Vanguard		NOAA (ATS-3)	FAA (ATS-5)	MARAD	NASA/PLACE		RARR**	Zulu Day	
			Pioneer	Skylab			ATS-3 & ATS-5	ATS-3 & 5	ATS-5 Only			
Sun.	1	NASA-PLACE			1050-2230Z (each day)		0000Z-0100Z; 1700Z-2400Z (each weekday except RARR days and as noted)	{0000-0100;} 4.0 Hrs. {2100-2400;} 4.0 Hrs.			1/4	Sailing Days after Pioneer-G Launch
	2	NASA-PLACE						0000-0100: 1.0 "			2/5	
	3	NASA-PLACE						0100-0400: 3.0 Hrs.	0400-0600		3/6	
	4	NASA-PLACE	2000-2400					0100-0400: 3.0 "	0400-0600		4/7	
	5	SATCOM Configuration	0000-2400							1600-2400	5/8	
	6	*Pioneer-G Launch	0000-2000							0000-0700	6/0	
										1600-2400		
Sat.	7	NASA-PLACE						2100-2400: 3.0 Hrs.		0000-0700	7/1	
Sun.	8	NASA-PLACE						{0000-0100;} 4.0 " {2100-2400;} 4.0 "			8/2	
	9	NASA-PLACE						0000-0100: 1.0 "			9/3	
	10	NASA-PLACE						0100-0600: 5.0 Hrs.			10/4	
	11	NASA-PLACE						0100-0600: 5.0 "			11/5	
	12	NASA-PLACE						0100-0600: 5.0 "			12/6	
	13	NASA-PLACE						0100-0600: 5.0 "			13/7	
Sat.	14	NASA-PLACE						{0100-0600;} 5.5 " {2330-2400;} 5.5 "	2100-2330		14/8	
Sun.	15	NASA/PLACE						{0000-0300;} 6.0 " {2100-2400;} 6.0 "	1930-2100		15/9	
	16	NASA/PLACE***						0000-0100: 1.0 "		1600-2400	16/10	
	17							Totals - 59.0 Hrs. for Sea Tests	9.5 Hrs.	0000-0700	17	
	18									1700-2400	18	
	19										19	
	20										20	
Sat.	21										21	
Sun.	22										22	
	23					1430-1800	1800Z - 2400Z				23	
	24					1330-1700	0000-0200; 1700-2400				24	
	25					1415-1800	0000-0100; 1800-2400				25	
	26						0000-0200; 1800-2400				26	
	27						0000-0200; 1800-2400				27	
Sat.	28	End of Pioneer Window					0000-0200				28	
Sun.	29						-				29	
	30						-				30	

\*PIONEER-G launched on schedule.

\*\*RARR - Range and Range Rate.

\*\*\*Vanguard docks @ Buenos Aires, Argentina before proceeding to Mar Del Plata, Argentina.

Table 3-2  
NASA/PLACE ATS-5 TRILATERATION TESTS  
(Rosman, Mojave and \*Vanguard Stations)

	Zulu Day	May 1973	NOAA (ATS-3)	FAA (ATS-5)	MARAD ATS-3 and ATS-5	NASA/PLACE Trilateration	No. Hrs. (ATS-5 only)	**RARR	Zulu Day
	1	NASA/PLACE/GE Trilateration (ATS-5)	1050Z-2230Z (each day) ↓		0000Z-0100Z; 1700Z-2400Z (each weekday except RARR days and as noted)	1400 - 1700	3.0 Hrs.	1600-2400 0000-0700	1
	2								2
	3								3
Sat.	4								4
	5								5
Sun.	6								6
	7								7
	8								8
	9								9
	10								10
	11	**** { SKYLAB (SL-1) Launch { SKYLAB (SL-2) Launch						1500-2400 0000-0700	11
Sat.	12								12
Sun.	13								13
	14								14
	15								15
	16								16
	17								17
	18								18
Sat.	19								19
Sun.	20								20
	21	NASA/PLACE/GE Trilateration (ATS-5)		1430-1800	1800Z - 2400Z	0800Z - 2400Z } 0000Z - 0800 Z }	24.0 Hrs.***		21
	22			1330-1700	0000 -0200 ; 1700 -2400				22
	23			1415-1800	0000 -0100 ; 1800 -2400				23
	24			↓	0000 -0200 ; 1800 -2400				24
Sat.	25				0000 -0200 ; 1800 -2400				25
Sun.	26				0000 - 0200				26
	27								27
	28								28
	29								29
	30								30
	31							1500-2400 0000-0700	31

\*Vanguard docked @ Mar Del Plata, Argentina, @ 57°W., 38°S.

\*\*Range and Range Rate (RARR)

\*\*\*Assume three 8-hr. crew-shifts @ Rosman, Mojave and Vanguard Terminals.

\*\*\*\*SKYLAB support by earth-based SATCOM terminal in-land @ Mar Del Plata.

Table 3-2 (continued)  
NASA/PLACE ATS-5 TRILATERATION TESTS  
(Rosman, Mojave and \*Vanguard Stations)

	Zulu Day	June 1973	NOAA (ATS-3)	FAA (ATS-5)	MARAD ATS-3 and ATS-5	NASA/PLACE Trilateration	No. Hrs. (ATS-5 only)	**RARR	Zulu Day
Sat. Sun.	1	NASA/PLACE/GE Trilateration (ATS-5)	1050Z-2230Z (each day)		0000Z-0100Z; 1700Z-2400Z (each weekday except RARR days)	0800Z to 2400Z } 0000Z to 0800Z }	24.0 Hrs.***		1
	2								2
	3								3
	4								4
	5								5
	6								6
	7								7
Sat. Sun.	8	NASA/PLACE Trilateration (ATS-5)				0800Z to 2400Z } 0000Z to 0800Z }	24.0 Hrs.***		8
	9								9
	10								10
	11								11
	12								12
	13							1600-2400 0000-0700	13
	14								14
Sat. Sun.	15	NASA/PLACE Trilateration (ATS-5)				0800Z to 2400Z } 0000Z to 0800Z }	24.0 Hrs.***		15
	16								16
	17								17
	18								18
	19								19
	20								20
	21								21
Sat. Sun.	22	NASA/PLACE Trilateration (ATS-5)				0800Z to 2400Z } 0000Z to 0800Z }	24.0 Hrs.***		22
	23								23
	24								24
	25								25
	26								26
	27							1600-2400 0000-0700	27
	28								28
Sat.	29	NASA/PLACE Trilateration (ATS-5)				0800Z to 2400Z } 0000Z to 0800Z }	24.0 Hrs.***		29
Sun.	30								30

\* Vanguard docked @ Mar Del Plata, Argentina, @ 57°W., 38°S.

\*\* Range and Range Rate (RARR)

\*\*\* Assumes three 8-hr. crew-shifts @ Rosman, Mojave and Vanguard Terminals.

\*\*\*\* SKYLAB support by earth-based SATCOM terminal in-land @ Mar Del Plata.

## APPENDIX 4

VANGUARD AND ROSMAN-STATION INSTRUMENTATION,  
VANGUARD/PLACE EXPERIMENT, SEA TESTS

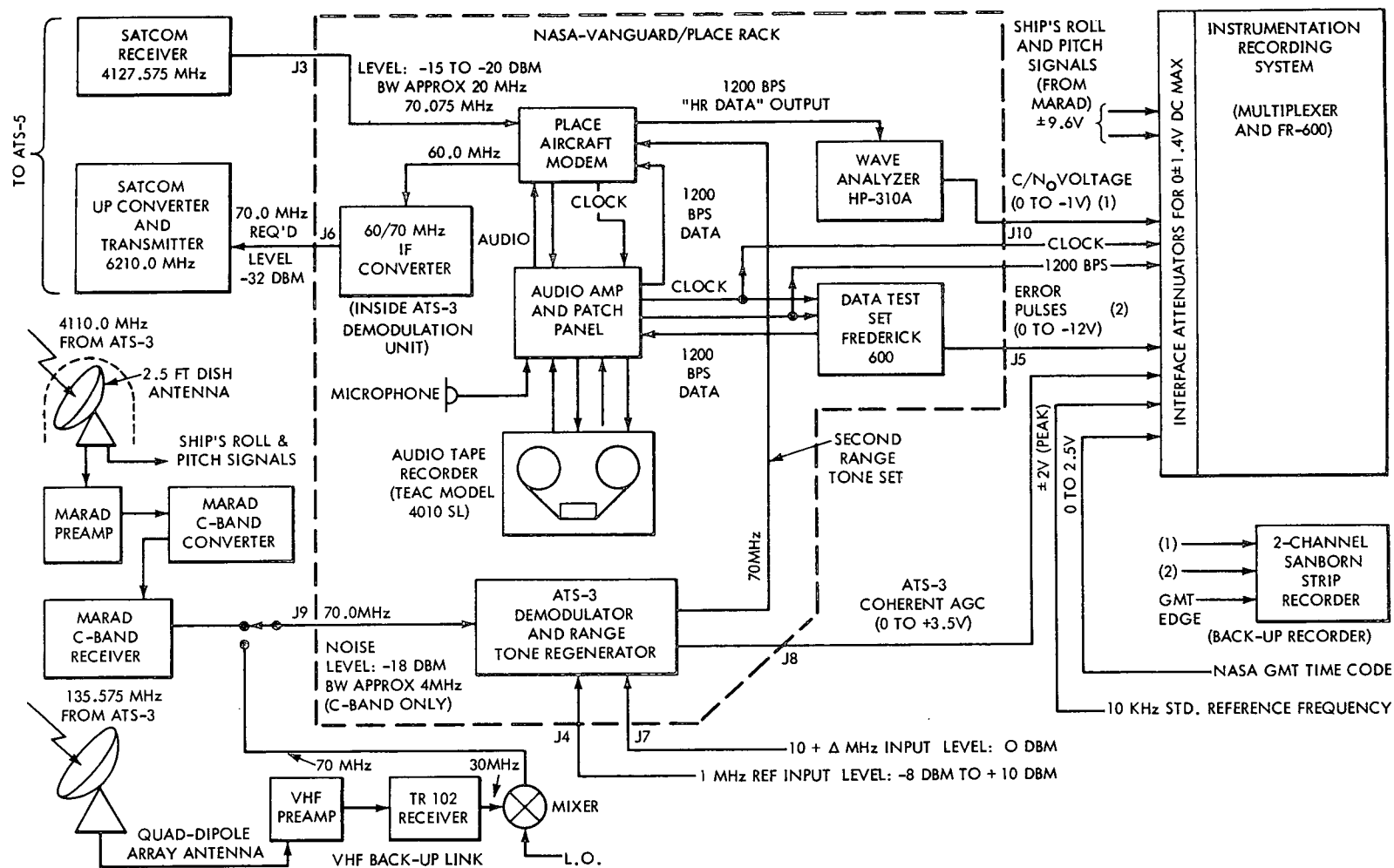


Figure 4-1. Vanguard/Place experiment, Sea Tests, Vanguard Instrumentation

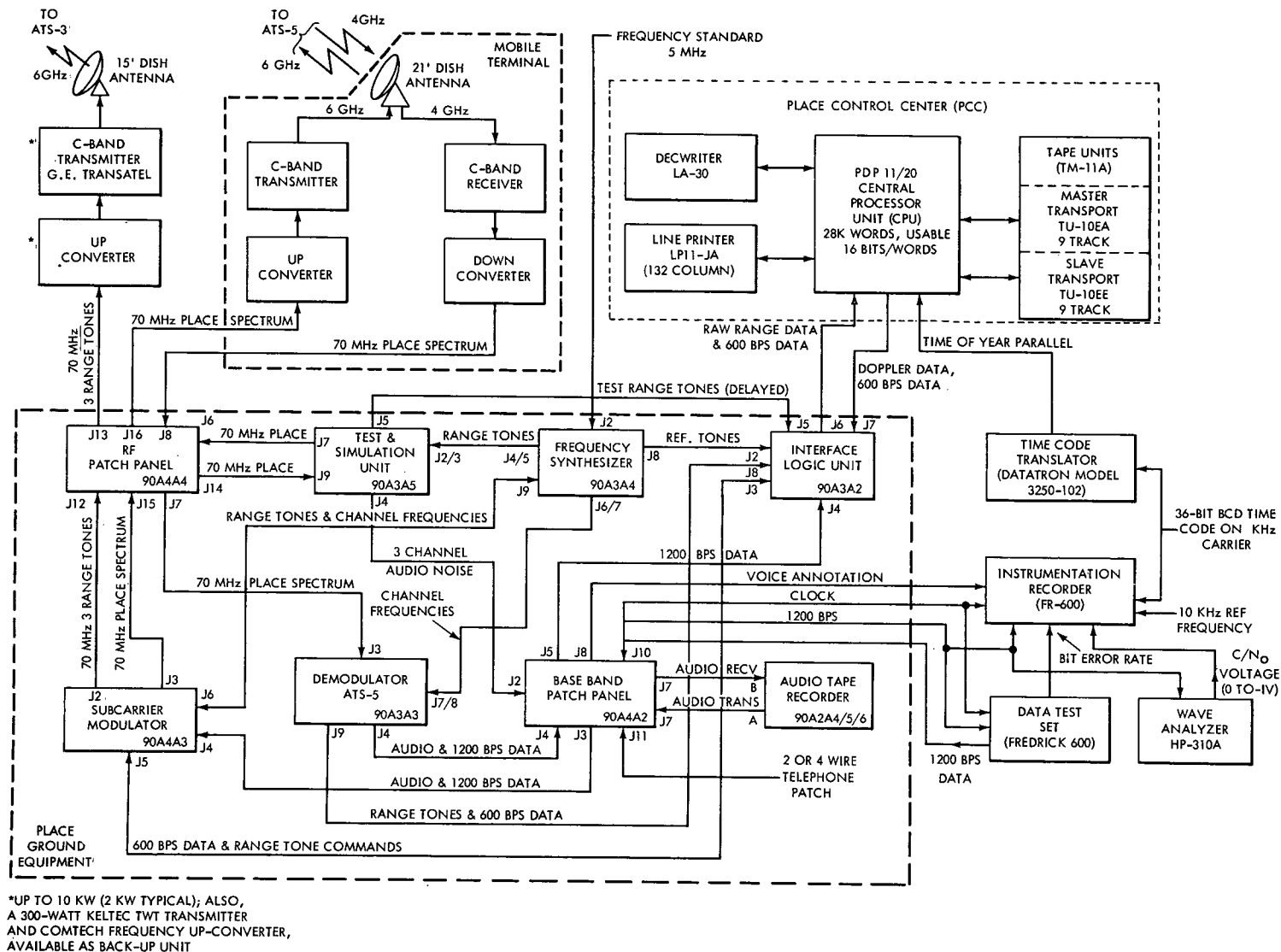


Figure 4-2. Rosman Station Place Configuration, Vanguard Sea Tests

Table 4-1  
Vanguard/PLACE Experiment, Sea Test, Vanguard  
FR-600 Recorder-Channel Allocation

FR-600 Track #	Record Module	IRIG Subcarrier #	IRIG Frequency Response (Hz)	Measured Parameter
1	FM			1200-bps clock
2	Direct			10-kHz Standard Reference Frequency (±2 volts, peak)
3	FM			1200-bps Raw Data from Modem
4	Multi- plexed on Direct Channel	1	6	Ship's pitch signal (±9.6 volts)
		3	11	Ship's Roll signal (±9.6 volts)
		5	20	Unassigned
		7	35	Unassigned
		8	45	ATS-3 Coherent – AGC (0 to +3.5 volts)
		13	220	C/N <sub>0</sub> Voltage, ATS-5 AGC (0 to -1.0 vdc)
5	Direct			Raw Bit-Error pulses from Frederick 600 (0 to -12 vdc)
6	Direct			GMT Time NASA Code 36-Bit, BCD, 1/sec., 1 KHz carrier (0 to 2.5 vdc)
Edge of Track				Voice Annotation

Tape Speed: 3-3/4 inches/sec. (3 hrs./reel)

Type Tape: 1-mil tape, 10-in. reel.

Table 4-2  
Vanguard/PLACE Experiment, Sea Tests, Rosman  
Station FR-600 Recorder-Channel Allocation

FR-600 Track #	Record Module	IRIG Subcarrier #	IRIG Frequency Response (Hz)	Measured Parameter
1	FM	7  13	35  220	1200-bps clock
2	Direct			10-kHz standard reference frequency (±2 volts, peak)
3	FM			1200-bps Raw Data from Modem
4	Multi- plexed on Direct Channel			Unassigned
5	Direct			C/N <sub>0</sub> Voltage ATS-5 AGC <sub>0</sub> (0 to -1.0 vdc)
6	Direct			Raw Bit-Error pulses from Frederick 600 (0 to -12 vdc)
Edge of Track				GMT Time Code, 36- bit, BCD, 1/sec., 1 kHz carrier (0 to 2.5 vdc)
				Voice Annotation

Tape Speed: 3-3/4 inches/sec. (3 hrs./reel)

Type Tape: 1-mil tape, 10-in. reel

**APPENDIX 5**

**VHF, BACKUP, RF-LINK BUDGET CALCULATION**

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UNITED STATES GOVERNMENT

# Memorandum

TO : H. Pedolsky  
ATS Project, Code 460

FROM : R. E. Taylor  
Navigation & Data Collection Branch, Code 752

SUBJECT: VHF-Backup Link for VANGUARD/PLACE Experiment

DATE: February 15, 1973

It is requested that a VHF-backup link, from Rosman-to-ATS-3 and down to the Vanguard, be made available for the VANGUARD/PLACE Experiment. The primary purpose of the VHF link is to provide a backup link as an option for the Rosman C-band link to ATS-3, the second satellite. The VHF link should be available from March 5, 1973, until the Vanguard docks at Mar Del Plata, Argentina.

Discussions with E. Ferrick, Code 861.0, indicate that the SCAMP antenna (new 9-element Yagi, 17 dB gain @ 149.220 MHz), and 2.5 kw VHF transmitter, can be made available at Rosman for the subject tests. Also, discussions with the Telemetry Engineer on the Vanguard (Steve Liptak) indicate that a Quad-Dipole Array, VHF preamplifier, and TR 102 VHF Receiver are available on the Vanguard for the subject tests. Code 750 will provide the necessary IF converter to translate the 30 MHz IF output, from the TR 102 Receiver, up to a 70 MHz IF required for the VANGUARD/PLACE electronics.

Attached is an ATS-3 VHF Link calculation, for Rosman to the Vanguard path, for the subject test. The 135.600 MHz downlink (100 KHz bandwidth) is the weaker link, but the carrier-to-noise power density value of 49.5 dB-Hz, out of the TR 102 receiver, is sufficient for the PLACE ranging tones.

Unique problems for VHF operation, compared to C-band, include larger values of time delay in the satellite transponder, VHF transmitter and receiver; and increased ranging bias and variance due to the ionosphere. However, the increased time delay is a matter of calibration whereas, the ranging bias due to the ionosphere can be removed from the data. Paul Schmid, Jr., Code 591, estimates that the residual range bias, after correction, is to to 100 meters rms at 136 MHz. This value compares with that expected for C-band operation.

ATS-3 operation at VHF, when scheduled, will be required for GMT times previously established for NASA/VANGUARD by ATSOCC.

Ralph E. Taylor  
Navigation & Data Collection Branch

Attachment



*Buy U.S. Savings Bonds Regularly on the Payroll Savings Plan*

Table 5-1  
ATS-3, VHF, RF-Link Calculation for VANGUARD/PLACE  
Experiment (Rosman to Vanguard)

Item	149.220-MHz Uplink	135.575-MHz Downlink
Transmit Antenna Gain (dB)	17	0
Transmit Network Loss (dB)	- 1	- 1
Transmitter Power Out (dBW)	34 (2.5 kW)	14 (25 W)
ERP (dBW)	50	13
Receive Antenna Gain (dB)	0	8 (CP)
Receive Network Loss (dB)	- 2	- 0.5
Free Space Loss (dB)	-167	-166
Atmospheric Loss (dB)	0	0
Polarization Loss (dB)	- 3	- 3.0
S/C Antenna Point Loss (dB)	0	0
Ground Antenna Point Loss (dB)	- 1	- 1
Net Propagation Loss (dB)	-171	-170
Received Carrier Power (dBW)	-123	-149.5
Receive Effective Noise Temperature ( $^{\circ}$ K)	435 (4 dB)	290 (3 dB)
Receive Antenna Noise Temperature ( $^{\circ}$ K)	700	600
Noise Power Density (dBW/Hz)	-198.0	-199.0
Carrier/Noise Power Density $C/N_0$ (dB-Hz)	75.0	49.5

APPENDIX 6

OPERATIONS-READINESS TESTS, VANGUARD/PLACE  
EXPERIMENT

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Table 6-1  
Satellite Modes and Station Configurations,  
Vanguard/PLACE Sea Tests

A. SATELLITE MODES:

MODE A (ATS-5):

- C-band omnidirectional antenna (orthogonal-linear polarization, transmit and receive)
- 2 TWT's
- #1 Transponder
- Frequency-Translation (FT) Mode

MODE B (ATS-3):

- C-band directive antenna (co-linear polarization, transmit and receive)
- 2 TWT's
- #1 Transponder
- FT Mode

MODE C (ATS-3 Backup):

- VHF Mode (100 KHz BW)
- ERP 43 dBm (full power) @ 135.575-MHz carrier frequency
- 8-element omnidirectional antenna

B. STATION CONFIGURATIONS:

CONFIGURATION 1 (Rosman 21-ft. Mobile Terminal):

- Up-link carrier frequency – 6220.075 MHz to ATS-5
- Transmitter power (total) – 2 kw
- Down-link carrier frequency – 4127.575 MHz
- Antenna-polarization: orthogonal-linear, transmit and receive

Table 6-1 (Continued)

CONFIGURATION 2 (Vanguard, 30-ft. SATCOM Terminal):

- Up-link carrier frequency – 6210.00 MHz to ATS-5
- Transmitter power – 3 kw (total)
- Down-link carrier frequency – 4127.575 MHz

CONFIGURATION 3 (Rosman – VHF Transmit):

- SCAMP antenna to ATS-3
- Transmitter power – 2.5 kw (total) @ 149.22 MHz

CONFIGURATION 4 (Vanguard – VHF Receive):

- Down-link carrier frequency – 135.575 MHz from ATS-3
- VHF, Quad-Dipole, Array receive antenna

CONFIGURATION 5 (Vanguard, Marad, 2.5 ft., C-band Terminal):

- Down-link 4110.00 MHz from ATS-3
- 2.5 ft. dish antenna pointing at ATS-3
- C-band preamp., Frequency down-converter, and receiver
- Antenna polarization-circular

CONFIGURATION 6 (Rosman, 15-ft., Dish-Transmit Terminal):

- Up-link carrier frequency – 6202.5 MHz to ATS-3
- Transmitter power – 2 kw (total)
- Down-link carrier frequency to Vanguard – 4110.0 MHz
- Antenna polarization – Linear (adjustable).

Note: All frequencies listed above, in Table 6-1, refer to the S and R Channel Center Frequency,  $f_0$  (see Figures 3 and 5).

Table 6-2  
Schedule of Operations-Readiness Tests, Vanguard/PLACE Experiment Sea Tests

Zulu Day (1973)	Zulu Time (Hrs.- Mins.)	No. Hrs.	Satellite Mode	Station Configuration	Operations-Readiness Tests
March 5	2330Z-0330Z	4.0	Mode A	1	PLACE 2-way ranging, 2-way voice, and 2-way, 1200 bps, data communications between Rosman and ATS-5.
March 6	2300Z-0100Z	2.0	Mode A	1, 2, 3, and 4	PLACE 2-way ranging, 2-way voice and 2-way, 1200 bps, data communications between Rosman & Vanguard via ATS-5. Ranging via VHF Back-up link thru ATS-3.
March 7	2330Z-0130Z	2.0	Mode A	1	PLACE 2-way ranging, 2-way voice and 2-way, 1200 bps, data communications between Rosman & ATS-5.
March 7	0300Z-0530Z	2.5	Mode A	1 and 2	PLACE 2-way ranging, 2-way voice and 2-way, 1200 bps, data communications between Rosman & Vanguard via ATS-5.
March 12	2330Z-0100Z	1.5	Modes A & C	1, 2, 3, and 4	PLACE-position location of Vanguard @ Port Canaveral: C-band via ATS-5 and VHF via ATS-3. 2-way voice and 2-way, 1200 bps, data communications tests.
March 13	0100Z-0345Z	2.75	Modes A & B	1, 2, 5, and 6	Evaluate shipboard radio-frequency interference (RFI) on C-band links. PLACE position-location of Vanguard @ Port Canaveral via C-band links thru ATS-5 and ATS-3.

Table 6-2 (continued)

Zulu Day (1973)	Zulu Time (Hrs.- Mins.)	No. Hrs.	Satellite Mode	Station Configuration	Operations-Readiness Tests
March 13	0345Z-0530Z	1.75	Mode A	1 & 2	Evaluate PLACE multiple-access capability, including measurement of intermodulation products.
March 14, 15 & 16	0100Z-0345Z	2.75/day	Modes A & B	1, 2, 5, and 6	PLACE-position location of Vanguard @ Port Canaveral via C-band links thru ATS-5 and ATS-3.
	0345Z-0530Z	1.75/day	Mode A	1 & 2	PLACE 2-way ranging to Vanguard @ Port Canaveral via C-band links thru ATS-5 & ATS-3. Unmodulated-carrier calibration tests; voice and 1200 bps data communications.
March 17	0100Z-0345Z	2.75	Modes A & B	1, 2, 5, & 6	PLACE-position location of Vanguard @ Port Canaveral.
March 20 thru 23	2300Z-2400Z	1.0/day	Modes A & B	1, 2, 5, & 6	PLACE-position location of Vanguard @ Port Canaveral. "Quick-look" tests using PLACE spectrum fully loaded. 2-way voice, and 2-way, 1200 bps, data communications between Rosman & Vanguard.
March 20 thru 24	0330Z-0600Z	2.5/day	Mode A	1 & 2	PLACE 2-way ranging, and determination of ship's location by a computed Line-of-Position (LOP) & an earth coordinate passing thru ship.
March 25 & 26	0030Z-0330Z	3.0/day	Modes A & B	1, 2, 5 & 6	PLACE 2-way ranging & determination of ship location.

**APPENDIX 7**

**SEA-TEST SCENARIO, VANGUARD/PLACE EQUIPMENT**

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Table 7-1  
Sea-Test Scenario, VANGUARD/PLACE Experiment

1973 Zulu Day	Sailing Day	ATS-3 and ATS-5		Sea Test (Note 1)	ATS-5		Sea Test (Notes 2, 3, & 4)
		Zulu Time (Hrs-Min)	No. Hrs.		Zulu Time (Hrs-Min)	No. Hrs.	
March 30	2	2330-2400	0.5	PLACE position-location of Vanguard @ 10 ranging points/minute; S&R channel only; total carrier-to-noise power density, $C/N_o = 46$ dB-Hz (all RF links)			
March 31	3	0000-0400 } 2100-2400 }	7.0	Repeat Sailing Day 2, except test full PLACE spectrum for 1.0 hr.	0400-0530	1.5	Single-satellite LOP measurement, and simultaneous 2-way voice and 2-way, 1200-bps, data tests. Ten ranging points per minute; S&R channel $C/N_o$ @ 44 dB-Hz (both Rec. RF links)
April 1	4	0000-0100 } 2100-2400 }	4.0	Repeat Sailing Day 2			
April 2	5	0000-0100	1.0	Repeat Sailing Day 2			

Table 7-1 (continued)

1973 Zulu Day	Sailing Day	ATS-3 and ATS-5		Sea Test (Note 1)	ATS-5		Sea Test (Notes 2, 3, & 4)														
		Zulu Time (Hrs-Min)	No. Hrs.		Zulu Time (Hrs-Min)	No. Hrs.															
April 3	6	0100-0400	3.0	2.5 hrs. same as Sailing 2. Additional 0.5 hr. same as Sailing Day 2 but set S&R chan. C/N <sub>o</sub> @ 42 dB-Hz, using full PLACE spectrum with unmodulated Voice (C/N <sub>o</sub> @ 46 dB-Hz) & H-R Data (C/N <sub>o</sub> @ 42 dB-Hz) channels set as follows to test for intermodula- tion (IM) product:  <table><tr><td><u>Channel</u></td><td><u>Channel Setting</u></td></tr><tr><td>V<sub>1</sub></td><td>09</td></tr><tr><td>V<sub>2</sub></td><td>22</td></tr><tr><td>V<sub>3</sub></td><td>25</td></tr><tr><td>D<sub>1</sub></td><td>47</td></tr><tr><td>D<sub>2</sub></td><td>53</td></tr><tr><td>D<sub>3</sub></td><td>55</td></tr></table>	<u>Channel</u>	<u>Channel Setting</u>	V <sub>1</sub>	09	V <sub>2</sub>	22	V <sub>3</sub>	25	D <sub>1</sub>	47	D <sub>2</sub>	53	D <sub>3</sub>	55	0400-0600	2.0	Repeat Sailing Day 3, except use full PLACE spectrum & test Multiple-Access capability.
<u>Channel</u>	<u>Channel Setting</u>																				
V <sub>1</sub>	09																				
V <sub>2</sub>	22																				
V <sub>3</sub>	25																				
D <sub>1</sub>	47																				
D <sub>2</sub>	53																				
D <sub>3</sub>	55																				

Table 7-1 (continued)

1973 Zulu Day	Sailing Day	ATS-3 and ATS-5		Sea Test (Note 1)	ATS-5		Sea Test (Notes 2, 3, & 4)														
		Zulu Time (Hrs-Min)	No. Hrs.		Zulu Time (Hrs-Min)	No. Hrs.															
April 4	7	0100-0400	3.0	Repeat Sailing Day 6 ex- cept set unmodulated Voice & Data channels as follows:  <table><tr><td><u>Channel</u></td><td><u>Channel Setting</u></td></tr><tr><td>V<sub>1</sub></td><td>09</td></tr><tr><td>V<sub>2</sub></td><td>12</td></tr><tr><td>V<sub>3</sub></td><td>15</td></tr><tr><td>D<sub>1</sub></td><td>18</td></tr><tr><td>D<sub>2</sub></td><td>21</td></tr><tr><td>D<sub>3</sub></td><td>24</td></tr></table>	<u>Channel</u>	<u>Channel Setting</u>	V <sub>1</sub>	09	V <sub>2</sub>	12	V <sub>3</sub>	15	D <sub>1</sub>	18	D <sub>2</sub>	21	D <sub>3</sub>	24	0400-0600	2.0	Repeat Sailing Day 3
<u>Channel</u>	<u>Channel Setting</u>																				
V <sub>1</sub>	09																				
V <sub>2</sub>	12																				
V <sub>3</sub>	15																				
D <sub>1</sub>	18																				
D <sub>2</sub>	21																				
D <sub>3</sub>	24																				
April 7	*T <sub>1</sub> +1	2100-2400	3.0	Repeat Sailing Day 2.	—	—	—														
April 8	T <sub>1</sub> +2	0000-0100 } 2100-2400 }	4.0	Repeat Sailing Day 2, except test full PLACE spectrum for 1.0 hr.	—	—	—														
April 9	T <sub>1</sub> +3	0000-0100	1.0	Repeat Sailing Day 2.	—	—	—														
April 10	T <sub>1</sub> +4	0100-0600	5.0	Repeat Sailing Day 2, ex- cept test full PLACE spectrum for 2.5 hr.	—	—	—														
April 11	T <sub>1</sub> +5	0100-0600	5.0	Repeat Sailing Day 2, ex- cept test full PLACE spectrum for 2.5 hr.	—	—	—														

Table 7-1 (continued)

1973 Zulu Day	Sailing Day	ATS-3 and ATS-5		Sea Test (Note 1)	ATS-5		Sea Test (Notes 2, 3, & 4)
		Zulu Time (Hrs-Min)	No. Hrs.		Zulu Time (Hrs-Min)	No. Hrs.	
April 12	*T <sub>1</sub> +6	0100-0600	5.0	Repeat Sailing Day 2, except test full PLACE spectrum for 2.5 hr.	—	—	—
April 13	T <sub>1</sub> +7	0100-0600	5.0	Repeat Sailing Day 2, except test full PLACE spectrum for 2.5 hr.	—	—	—
April 14	T <sub>1</sub> +8	0100-0600 } 2330-2400 }	5.5	Repeat Sailing Day 2, except test full PLACE spectrum for 2.5 hr.	2100-2330	2.5	Repeat Sailing Day 3
April 15	T <sub>1</sub> +9	0000-0300 } 2100-2400 }	6.0	Repeat Sailing Day 2.	1930-2100	1.5	Repeat Sailing Day 3
April 16	T <sub>1</sub> +10	0000-0100	1.0	Repeat Sailing Day 2.	—	—	—

- NOTES: 1. Satellite Modes A & B; Station Configurations 1, 2, 5, & 6 (Appendix 6)  
 2. Satellite Mode A; Station Configurations 1 & 2 (Appendix 6)  
 3. Line-of-position (LOP) using ATS-5 only; compute (off line) ship's position by convolution with single geometric coordinate (longitude or latitude) passing through ship.  
 4. See Appendix 8 for schedule of voice tests.

\*T<sub>1</sub> Corresponds to time when Vanguard departs from PIONEER TSP.

APPENDIX 8

VOICE TESTS, VANGUARD/PLACE EXPERIMENT

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Table 8-1  
Schedule for Voice Tests, Vanguard Place Experiment

Date: 31 March 73 . . . . . 1.5 hrs.

Zulu Time (Hrs.-Min.)	Item
0400-0402	Set Up
0402-0419	Test Tape #2
0419-0424	Set Up
0424-0511	Test Tape #3
0511-0516	Set Up
0516-0528	Test Tape #4
0528-0530	No transmission

Date: 3 April 73 . . . . . 2.0 hrs.

Alternate

Zulu Time (Hrs.-Min.)	Item	Zulu Time (Hrs.-Min.)	Item
0400-0504	Telephone Net Test	0400-0402	Set Up
0504-0509	Set Up	0402-0449	Test Tape #1
0509-0556	Test Tape #2	0449-0454	Set Up
		0454-0541	Test Tape #2
		0541-0600	Command and Execution

Date: 4 April 73 . . . . . 2.0 hrs.

Zulu Time (Hrs.-Min.)	Item
0400-0402	Set Up
0402-0449	Test Tape #4
0449-0454	Set Up
0454-0541	Test Tape #5
0541-0600	Command and Execution

Table 8-1. (continued)

Date: 10 April 73 ..... 2.5 hrs.

Zulu Time (Hrs.-Min.)	Item
0330-0332	Set Up
0332-0419	Test Tape #2
0419-0424	Set Up
0424-0511	Test Tape #3
0511-0516	Set Up
0516-0528	Test Tape #4
0528-0533	Set Up
0533-0545	Test Tape #5
0545-0600	Command and Execution

Date: 11 April 73 ..... 2.5 hrs.

Zulu Time (Hrs.-Min.)	Item
0330-0332	Set Up
0332-0419	Test Tape #1
0419-0424	Set Up
0424-0511	Test Tape #2
0511-0516	Set Up
0516-0528	Test Tape #4
0528-0533	Set Up
0533-0545	Test Tape #5
0545-0600	Command and Execution

Date: 12 April 73 ..... 2.5 hrs.

Alternate

Zulu Time (Hrs.-Min.)	Item	Zulu Time (Hrs.-Min.)	Item
0330-0434	Telephone Net Test	0330-0332	Set Up
0434-0439	Set Up	0332-0419	Test Tape #3
0439-0526	Test Tape #1	0419-0424	Set Up
0526-0531	Set Up	0424-0511	Test Tape #1
0531-0543	Test Tape #4	0511-0516	Set Up
0543-0548	Set Up	0516-0528	Test Tape #4
0548-0600	Test Tape #5	0528-0533	Set Up
		0533-0545	Test Tape #5
		0545-0600	Command and Execution

Table 8-1 (continued)

Date: 13 April 73 ..... 2.5 hrs.

Zulu Time (Hrs.-Min.)	Item
0330-0332	Set Up
0332-0419	Test Tape #2
0419-0424	Set Up
0424-0511	Test Tape #3
0511-0516	Set Up
0516-0528	Test Tape #4
0528-0533	Set Up
0533-0545	Test Tape #5
0545-0600	Command and Execution

Date: 14 April 73 ..... 2.5 hrs.

Zulu Time (Hrs.-Min.)	Item
2100-2102	Set Up
2102-2149	Test Tape #1
2149-2154	Set Up
2154-2241	Test Tape #2
2241-2246	Set Up
2246-2258	Test Tape #4
2258-2303	Set Up
2303-2315	Test Tape #5
2315-2330	Command and Execution

Voice Testing (total) ..... 18.0 hrs.



Table 8-2  
Definitions for Voice-Test Tapes

<p><u>TAPE # 1: 47 MINS</u></p> <p>A-5 50 WORDS OF MRT 10 SCIM SIGNALS 50 WORDS OF PB APOLLO # 224 10 SCIM</p> <p>A-6 50 WORDS OF MRT 10 SCIM 50 WORDS OF PB APOLLO # 264 10 SCIM</p> <p>F-3 50 WORDS OF MRT 10 SCIM 50 WORDS OF PB APOLLO # 214 10 SCIM</p> <p>F-4 50 WORDS OF MRT 10 SCIM 50 WORDS OF PB APOLLO # 354</p> <p><u>TAPE # 2: 47 MINS</u></p> <p>E-1 50 WORDS OF MRT 10 SCIM SIGNALS 50 WORDS OF PB APOLLO # 244 10 SCIM</p> <p>E-2 50 WORDS OF MRT 10 SCIM 50 WORDS OF PB APOLLO # 254 10 SCIM</p> <p>B-1 50 WORDS OF MRT 10 SCIM 50 WORDS OF PB APOLLO # 284 10 SCIM</p> <p>B-2 50 Words of MRT 10 SCIM 50 WORDS OF PB APOLLO # 274</p>	<p><u>TAPE # 3: 47 MINS</u></p> <p>C-3 50 WORDS OF MRT 10 SCIM 50 WORDS OF PB APOLLO # 314 10 SCIM</p> <p>C-4 50 WORDS OF MRT 10 SCIM 50 WORDS OF PB APOLLO # 323 10 SCIM</p> <p>D-5 50 WORDS OF MRT 10 SCIM 50 WORDS OF PB APOLLO # 283 10 SCIM</p> <p>D-6 50 WORDS OF MRT 10 SCIM 50 WORDS OF PB APOLLO # 213 10 SCIM</p> <p><u>TAPE # 4:</u></p> <p>12 MINUTES OF MARITIME MSGS</p> <p><u>TAPE # 5:</u></p> <p>12 MINUTES OF A.T.C. MSGS</p>
<p>Legend: MRT – Modified Rhyme Test PB – Phonetically Balanced SCIM – Speech Communications Index Meter A.T.C. – Air Traffic Control</p>	

Table 8-3  
Telephone Network Free-Conversation Test Form

EXPERIMENT <u>NASA/VANGUARD</u>
NAME _____
ADDRESS _____
TELEPHONE # _____
TELEPHONE COMPANY _____
DATE OF TEST _____
TIME OF TEST _____
<b>1. CONVERSATION INTELLIGIBILITY (Please check one of the following)</b>  <input type="checkbox"/> Understood Complete Conversation  <input type="checkbox"/> Understood Complete Conversation With Moderate Difficulty  <input type="checkbox"/> Understood Complete Conversation With Appreciable Difficulty  <input type="checkbox"/> Understood Most Of The Conversation With Appreciable Difficulty  <input type="checkbox"/> Understood Little Or None Of The Conversation
<b>2. TRANSMISSION LINE QUALITY (Please check one of the following)</b>  <input type="checkbox"/> Background Completely Free Of Noise  <input type="checkbox"/> Background Slightly Noisy  <input type="checkbox"/> Background Very Noisy, But Understood Conversation Completely  <input type="checkbox"/> Background Very Noisy. Do Not Understand Conversation Completely Because of Noise Masking  <input type="checkbox"/> Background Noise Extremely High. Understand Little Or None Of The Conversation Because Of Noise Masking.

Table 8-3 (Continued)

3. VOICE QUALITY STATISTICS (Check appropriate box)

Recognized Person Speaking ☐ Yes ☐ No

Voice Distorted ☐ Yes ☐ No

Voice Appeared To Fade ☐ Yes ☐ No

4. BACKGROUND NOISE STATISTICS (Check appropriate box)

Noise level heard should be compared to the loudness of the voice heard.

Noise Type

Static ☐ NONE ☐ LOWER ☐ SAME ☐ HIGHER

Hum ☐ NONE ☐ LOWER ☐ SAME ☐ HIGHER

Ringing ☐ NONE ☐ LOWER ☐ SAME ☐ HIGHER

Putt Putt ☐ NONE ☐ LOWER ☐ SAME ☐ HIGHER

Typewriter ☐ NONE ☐ LOWER ☐ SAME ☐ HIGHER

Somebody Talking ☐ NONE ☐ LOWER ☐ SAME ☐ HIGHER

Other \_\_\_\_\_

5. GENERAL STATEMENT (Check only one)

Based on my previous experience with long distance calls I would say that the overall service provided was:

☐ Excellent

☐ Acceptable

☐ Not Acceptable

6. COMMENTS

Please state any comments that you may have with respect to this experiment.

APPENDIX 9

SATELLITE TRILATERATION THEORY AND COMPUTATIONS

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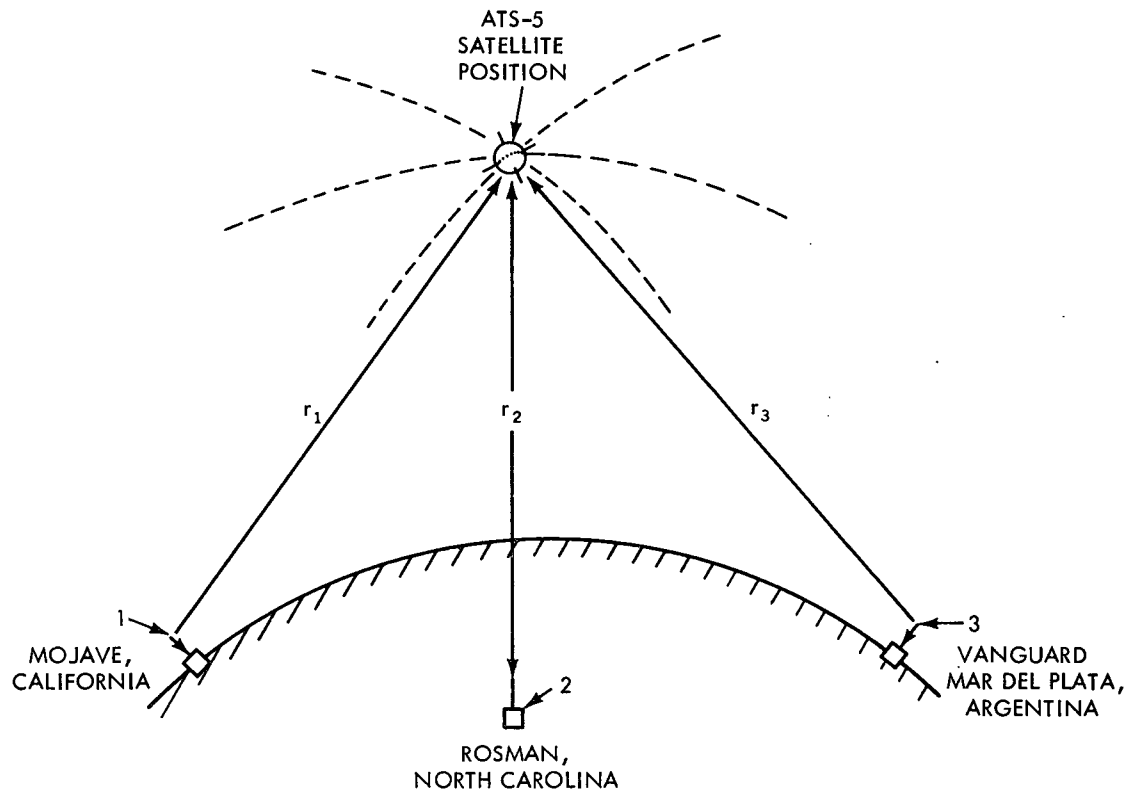


Figure 9-1. ATS-5 Satellite-Trilateration Tests

### SATELLITE TRILATERATION EQUATIONS

The state variable in the satellite-trilateration equations will be a six-dimensional vector:

$$\mathbf{x}^T = (L \quad \lambda \quad r/r_0 \quad \dot{L} \quad \dot{\lambda} \quad \dot{r}/r_0),$$

where

- $L$  = satellite longitude, positive west,
- $\lambda$  = satellite latitude, positive north,
- $r$  = satellite distance from earth's center,
- $r_0$  = nominal value of  $r$ ,

with distances in earth radii, angles in radians, and time in polling intervals (approximately minutes). The symbol  $\hat{\cdot}$  over a letter will indicate its estimated value; thus,

$\hat{x}_{k/1}$  = estimate of  $x$  at time  $k$ , using information up to time 1.

The following equations will be instrumented:

$$\hat{x}_{k/k-1} = \Phi \hat{x}_{k-1/k-1},$$

where

$$\Phi = \begin{pmatrix} I_3 & I_3 \\ O_3 & I_3 \end{pmatrix},$$

$I_3 = 3 \times 3$  identity matrix,

$O_3 = 3 \times 3$  zero matrix;

$$\hat{x}_{0/0}^T = (L_0 \ 0 \ 1 \ 0 \ 0 \ 0),$$

$L_0$  being the nominal satellite longitude (e.g.,  $105^\circ$  W.);

$$\hat{x}_{k/k} = \hat{x}_{k/k-1} + K_k (r_{ik} - \hat{r}_{ik/k-1}),$$

where

$r_{ik}$  = measured range from ground station  $i$  at time  $k$  ( $i = 1, 2, 3$ ),

$$\begin{aligned} \hat{r}_{ik/k-1} = \{ & \hat{r}_{k/k-1}^2 - 2\hat{r}_{k/k-1} r_{gi} [\sin \lambda_{gi} \sin \hat{\lambda}_{k/k-1} + \\ & \cos \lambda_{gi} \cos \hat{\lambda}_{k/k-1} \cos (L_{gi} - \hat{L}_{k/k-1})] + r_{gi}^2 \}^{1/2}, \end{aligned}$$

$$\hat{r}_{k/k-1} = r_0 (\hat{r}/r_0)_{k/k-1},$$

$\lambda_{gi}$  = geocentric latitude of ground station i,

$L_{gi}$  = longitude of ground station i,

$r_{gi}$  = distance of ground station i from earth's center, and the ground stations are numbered

1 – Mojave, California

2 – Rosman, North Carolina

3 – Mar del Plata, Argentina.

The gain matrix at the first polling time,  $K_1$ , is computed as follows:

1. Compute nominal ranges from the ground stations to the satellite:

$$r_{i0} = [r_0^2 - 2 r_0 r_{gi} \cos \lambda_{gi} \cos (L_{gi} - L_0) + r_{gi}^2]^{1/2};$$

2. Compute a  $3 \times 3$  matrix H, whose elements are

$$h_{i1} = - (r_0 r_{gi}/r_{i0}) \cos \lambda_{gi} \sin (L_{gi} - L_0),$$

$$h_{i2} = - (r_0 r_{gi}/r_{i0}) \sin \lambda_{gi},$$

$$h_{i3} = (r_0/r_{i0}) [r_0 - r_{gi} \cos \lambda_{gi} \cos (L_{gi} - L_0)];$$

3. Find the inverse of H;

4.

$$K_1 = \begin{pmatrix} H^{-1} \\ O_3 \end{pmatrix}.$$

The gain matrix at each subsequent polling time,  $K_k$  for  $k \geq 2$ . is a function only of the estimated satellite longitude:

$$K_k = \begin{pmatrix} -1. & .9 & .1 \\ .15 & -.7 & .5 \\ -.12 + .002 L_0 & .2 - .002 L_0 & .07 \\ -.33 & .26 & .07 \\ 0. & -.24 & .24 \\ -.03 + .0007 L_0 & .073 - .00057 L_0 & .04 \end{pmatrix}, k \geq 2,$$

where in this expression only  $L_0$  is in degrees.

Table 9-1

Satellite Trilateration-Error Computation for ATS-5 at 105° West Longitude

	Magnitude of Semi-Axes of Error Ellipsoid (km)	Direction Cosines of Each Axis Referenced to East/North/Vertical Coordinates*			
t = 1 Min.:	1.849	0.900	-0.434	-0.049	*
	0.563	0.435	0.901	0.012	
	0.058	0.039	-0.032	0.999	
	Velocity Error (km/min.)	Kalman-Filter Gain**			
t = 1 Min.:	0.596	1.000	0.0	0.0	**
	0.596	0.0	1.000	0.0	
	0.596	0.0	0.0	1.000	
t = 2 Min.:	1.358	0.895	-0.444	-0.048	*
	0.533	0.445	0.895	0.012	
	0.059	0.038	-0.032	0.999	
t = 2 Min.:	0.782	0.890	-0.453	-0.048	**
	0.654	0.454	0.891	0.014	
	0.547	0.037	-0.034	0.999	
t = 3 Min.:	1.276	0.889	-0.456	-0.048	*
	0.544	0.457	0.890	0.008	
	0.059	0.039	-0.030	0.999	
t = 3 Min.:	0.841	0.896	-0.441	-0.048	**
	0.640	0.441	0.897	0.005	
	0.539	0.041	-0.026	0.999	
t = 4 Min.:	1.312	0.890	-0.453	-0.048	*
	0.545	0.454	0.891	0.008	
	0.059	0.039	-0.029	0.999	
t = 4 Min.:	0.834	0.897	-0.439	-0.049	**
	0.627	0.440	0.898	0.011	
	0.538	0.039	-0.032	0.999	

Table 9-1. (continued)

Magnitude of Semi-Axes of Error Ellipsoid (km)		Direction Cosines of Each Axis Referenced to East/North/Vertical Coordinates *		
t = 5 Min.:	1.342	0.892	-0.449	-0.048
	0.543	0.449	0.893	0.009
	0.059	0.039	-0.029	0.999
	Velocity/Error (km/min.)		Kalman-Filter Gain **	
	0.807	0.894	-0.444	-0.050
	0.622	0.446	0.895	0.015
t = 6 Min.:	0.538	0.038	-0.035	0.999
	1.350	0.893	-0.447	-0.048
	0.543	0.448	0.894	0.009
	0.059	0.039	-0.030	0.999
	0.783	0.891	-0.452	-0.050
	0.621	0.453	0.891	0.015
t = 7 Min.:	0.538	0.038	-0.036	0.999
	1.346	0.893	-0.448	-0.048
	0.542	0.448	0.894	0.009
	0.059	0.039	-0.030	0.999
	0.768	0.888	-0.457	-0.050
	0.620	0.458	0.889	0.015
t = 8 Min.:	0.538	0.038	-0.036	0.999
	1.340	0.893	-0.448	-0.048
	0.542	0.449	0.893	0.009
	0.059	0.039	-0.030	0.999
	0.761	0.887	-0.459	-0.050
	0.620	0.460	0.888	0.015
	0.538	0.038	-0.036	0.999

Table 9-1. (continued)

Magnitude of Semi-Axes of Error Ellipsoid (km)		Direction Cosines of Each Axis Referenced to East/North/Vertical Coordinates *		
t = 9 Min.:	1.335	0.892	-0.449	-0.048
	0.542	0.450	0.893	0.009
	0.059	0.039	-0.030	0.999
	*			
	Velocity Error (km/min.)	Kalman-Filter Gain**		
	0.759	0.887	-0.459	-0.050
t = 10 Min.:	0.620	0.460	0.888	0.015
	0.538	0.038	-0.036	0.999
	**			
	1.333	0.892	-0.449	-0.048
	0.542	0.450	0.893	0.009
	0.059	0.039	-0.030	0.999
t = 10 Min.:	*			
	0.758	0.887	-0.458	-0.050
	0.620	0.460	0.888	0.015
	0.538	0.038	-0.036	0.999
	**			

Assumptions:

- (1) Trilateration stations @ Rosman, Mojave and Mar Del Plata (Position surveyed to an accuracy of 10 m).
- (2) Ranging-Measurement Error is 100-m, rms.
- (3) Random Satellite Motion: 420-m initial position error, each direction, and 25km/hr. velocity error; disturbances of 420 m and 25 km/hr. (all rms values) between ranging measurements made @ 1-minute intervals (i.e., t = 1, 2, 3, 4 min., etc.).